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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN NO. 77.
L. O. HOWARD, Entomologist and Chief of Bureau.

# HIBERNATION OF THE MEXICAN COTTON BOLL WEEVIL.

BY

W. E. HINDS AND W. W. YOTHERS,

UNDER THE DIRECTION OF

W. D. HUNTER.

ISSUED OCTOBER 18, 1909.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1909.

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# LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
*Washington, D. C., October 6, 1908.*

Sir: I have the honor to transmit herewith for publication as Bulletin No. 77, of the Bureau of Entomology, a manuscript prepared by Dr. W. E. Hinds and Mr. W. W. Yothers under the direction of Mr. W. D. Hunter. This manuscript deals with the hibernation of the Mexican cotton boll weevil. The winter season is a critical period in the life history of this very destructive pest. An exact knowledge of its hibernation throws much light on practical control. For this reason careful experimental studies have been carried on for several years. On account of their importance the results are presented somewhat in detail. The illustrations will add greatly to the clearness and force of the text.

Respectfully,

L. O. Howard,
*Entomologist and Chief of Bureau.*

Hon. James Wilson,
*Secretary of Agriculture.*

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# PREFACE.

Natural conditions annually reduce enormously the numbers of the cotton boll weevil. Although no two seasons are exactly alike, never more than a small percentage of the weevils in the fields in the fall is permitted to survive until spring. In fact, winter is the most critical season in the whole life history of the weevil. Any steps in control of the weevil during the winter are therefore much more important than those which can be taken at any other season of the year. To destroy ten weevils in the winter is much better than to destroy many thousands in the summer. The cotton boll weevil is now causing a damage in the United States each year of at least $25,000,000. The indications are that this amount will continue to be lost for some time at least on account of the difficulties in control which will be encountered in the Mississippi Valley. For these reasons the Bureau of Entomology has conducted careful investigations of the hibernation of the weevil and presents the somewhat detailed results in this bulletin.

Until this time the hibernation of the boll weevil has been less understood than any other phase of its life history. This was due to the great difficulty in obtaining the necessary data and the fact that the phenomena of hibernation are not necessarily identical in different seasons. In fact, it will be seen from the following pages that there have been very important dissimilarities between the years when special observations have been under way. The necessary repeated work in large cages in different localities has now been carried on and extensive field observations have been made in various representative parts of the infested area as to the natural situations in which the hibernating weevils occur. As a result, the present bulletin will make the life history of the boll weevil during the winter season at least as well known as any other portion of its biology.

In the work leading to this bulletin practical considerations have always received primary attention. However, it has repeatedly been shown that careful detailed investigations of injurious insects may result in important suggestions for control that are not foreseen at the beginning of the work. Therefore the topic of the hibernation of the boll weevil has been investigated from every possible standpoint. Its importance, as a critical period in the life history of a most injurious pest, has abundantly warranted this work.

Foremost among the points of immediate practical application shown in this bulletin is the enormous importance of the fall destruction of the plants. This has been one of the recommendations of the Bureau of Entomology for some years. Its importance will increase rather than diminish in the regions now invaded by the insect. The cage experiments at Dallas, Calvert, and Victoria, Tex., in the winter of 1906–7 have given most important and accurate data showing exactly what may be accomplished by the fall destruction of the plants at various dates. This bulletin, moreover, shows the most favorable and least favorable conditions in the hibernation of the weevil. This information can be put to practical use by every farmer in the infested area. It shows exactly where the most effective work can be done. A not unimportant feature is the showing of the absolute impracticability of late planting to obviate damage by the boll weevil by reason of the remarkable longevity of hibernated individuals without any green food whatever.

The information included in this bulletin has been accumulated through the investigations and observations of the numerous agents connected with the work during the seasons of 1902–1907. Some of the facts have been briefly stated in previous publications, particularly Bulletins 45 and 51. The manuscript for the present publication was prepared during the summer and fall of 1907, and since that time some of the conclusions drawn from this study have been published in connection with other bulletins and circulars relating to the weevil and its control. But in no other instance have all of the facts been considered or their complex, intimate, and important co-relationships studied as in this work.

On account of the large amount of work that has been done and the practical importance of many of the conclusions drawn it has been considered that full indication should be made in the bulletin of the methods by which the conclusions and recommendations are reached. Therefore special pains have been taken to give all essential data and to represent by charts matter that can thus be graphically expressed.

It will be noted that the various experiments dealt with in this bulletin are taken up according to the years in which the work was carried on. The result is that some special topics, such as time of entrance into hibernation, will be found discussed in several places. It has been found entirely impracticable to follow a strictly topical system and discuss each point connected with hibernation with reference to the work of the various years. This impracticability is due principally to the great natural variations in the seasons. Nevertheless the first part of the bulletin discusses the general feature of hibernation and the summary at the end has been written in such a way as to bring the principal conclusions on the various topics into condensed form.

The question of credit to the various investigators who have contributed to this bulletin is rather complicated. Mr. E. A. Schwarz studied carefully the hibernation of the weevil at Victoria, Tex., in the winter of 1901–2 and his observations have been utilized. Later Mr. Wilmon Newell, secretary of the State Crop Pest Commission of Louisiana, assisted by Mr. J. B. Garrett, planned and executed a series of experiments in the hibernation of the weevil which was much more extensive than any similar work that had been done up to that time in this country. This work was done in cooperation with the Bureau of Entomology, and the results, through the liberality of Mr. Newell, have been largely incorporated into this bulletin. Mr. J. D. Mitchell contributed important facts from observations during several seasons, especially with reference to actual winter field conditions. Many of the details in the plans for the extensive work of 1906–7 were worked out by Dr. W. E. Hinds, who also superintended the extensive tedious work necessary during the following spring. In all this work Doctor Hinds was assisted by Mr. W. W. Yothers, by Mr. A. C. Morgan, who had charge of the work with the large cage near Victoria, and by Mr. C. R. Jones, who was located at Calvert. Mr. Yothers collaborated with Doctor Hinds in the arrangement and correlation of the data obtained at the places mentioned and in placing in manuscript form the records of many of the experiments of previous years. For two winters Mr. Yothers carried on special observations, largely of his own planning, as to actual field conditions. In this work he collected large quantities of bolls and various forms of trash in and about cotton fields, and from careful examinations of this material in the laboratory he was able to determine many very important facts in regard to the several classes of rubbish, or winter shelter, which are most likely to protect weevils and to insure their successful survival through the winter season.

W. D. Hunter,
*In Charge of Southern Field Crop Insect Investigations.*

# HIBERNATION OF THE MEXICAN COTTON BOLL WEEVIL.

## ENTRANCE INTO HIBERNATION.

In the study of hibernation of the Mexican cotton boll weevil (*Anthonomus grandis* Boh.) we shall first consider the factors affecting the abundance of weevils which may enter hibernation, the dependence of the number of weevils present upon preceding conditions of food supply, the climatic conditions accompanying or producing the beginning of hibernation, and other biological facts which may be of interest or value in connection with this division of the subject.

### SUPPLY OF WEEVILS TO ENTER HIBERNATION.

The common name "cotton boll weevil," which is uniformly applied to this insect, may be in part at least responsible for a misleading impression in regard to the most common point of attack and place of development of this weevil. The common name was first applied because of the fact that in the first recorded case of this insect attacking cotton the specimens were found in bolls. It is a fact, however, that by far the greater number of weevils to be found in any field at any season of the year have really developed within the buds or squares, rather than within the bolls. In the first place, it is perfectly evident that during the entire growing season of the plant, in the infested area, probably not much more than 10 per cent of the squares which form ultimately produce bolls. For this reason the weevils find opportunities for reproduction many times greater in squares than in bolls. In the second place, a careful study of the habits of the weevils shows that they prefer squares both for feeding and for reproduction. In the third place, the average period required for development in squares is only one-half to one-third as great as it is in bolls which become more than one-half grown. These three considerations insure a far more rapid and abundant multiplication of individuals through the medium of squares than through bolls. Wherever weevils have been present in average abundance at the beginning of the season, unless they have been unusually checked by climatic conditions unfavorable to their development, a condition of total infestation of squares is usually reached between August 1

and 20. By this time practically all of the crop which can be expected will have been set and many of the oldest bolls will be found maturing. If a moderate crop of bolls is being matured the formation of squares usually ceases, almost if not entirely, for a period of several weeks. Whereas in the early part of the season female weevils could find abundant opportunities for depositing their eggs in previously uninfested squares, after the time of total infestation is reached such opportunities practically cease to exist. The available supply of squares and bolls becomes too small to support the large number of weevils which may be present, and conditions become decidedly unfavorable for their further multiplication. It is at this season of the year, usually from August 15 to September 20, that the largest general dispersion movements of the weevils take place. It is at this season also, during recent years, that the cotton leaf-worm has become sufficiently abundant to secure a partial or complete defoliation of the plants. While the occurrence of the leaf-worms is by no means regular, the effect of their work is to still further limit the available food supply of the boll weevil and to force them into a more general dispersion from the defoliated plants. On account of the reduced supply of squares, the increased period of development in bolls, and the extensive dispersion movements of the weevil at this season of the year, it usually happens that the actual number of individuals in a field becomes greatly reduced.

Following the maturity of a considerable portion of the crop of bolls, and usually in connection with the occurrence of a heavy rainfall, a renewed growth of the plant commonly produces an abundance of squares. It is this late top growth of the plant, which serves no good purpose so far as further production of cotton is concerned, that is primarily responsible in most fields for the needlessly large number of weevils produced between the time of maturity of the crop and the usual time of destruction of the plants by frost. A large proportion of the weevils which become adults before September 1 may be expected to die, either as cold weather comes on or during the early part of the winter season. The later-developed weevils, however, have not exhausted their vitality and are much more likely to survive the full hibernation period. The importance, therefore, of preventing or of reducing the formation of squares following the period of maturity of the bolls can be easily appreciated.

To sum up briefly the principal points in the development of weevils which may enter hibernation, we may say that from the beginning of the formation of squares until the plants are destroyed by frost the development of the boll weevil is a continuous process. During the usual fruiting period of the plant it is possible that as many as eight generations of the weevil may be produced, especially in southern Texas. It is also possible that during this

period individuals may exist which represent an advance of only one generation. During the entire season the average period required for development, in squares, from the deposition of the egg to the emergence of the adult weevil is from 18 to 20 days. In bolls the developmental period may exceed 60 days. The average period during which each female may deposit eggs is between 50 and 60 days. The average number of eggs which each female may be expected to deposit is not far from 100. The average period required for each generation is between 40 and 45 days. In southern Texas, therefore, five full generations of the weevil may usually be expected, and owing to the somewhat shorter season and lower temperatures occurring in northern Texas four generations is probably the true average in that section of the State. There is no particular hibernation brood, but representatives of all generations may survive and enter hibernation. From these considerations it will be readily understood that during the latter part of the season the multiplication is primarily dependent upon the food supply, and that the common practice of allowing stalks to stand after the crop becomes matured is primarily responsible for a large proportion of the weevils which may enter hibernation.

It is but repeating statements which have been frequently made in former publications of this investigation to say that the vain hope of securing some top crop of cotton, in case there should be a late fall, is probably the principal reason which has been urged for allowing this growth of the plant. So far as we know there is no record of a top crop ever having been secured in a field which had become thoroughly infested with boll weevils earlier in the season. While it is true that in uninfested regions some top crop has occasionally been formed and may occasionally be secured in the future, it is not putting the facts too strongly to say that within the weevil-infested area this has never occurred and should never be expected.

### STAGES ENTERING HIBERNATION.

The reproductive activity of the weevil continues steadily until the plants are destroyed by frost. It gradually decreases coincidently with the gradual decrease in heat. All stages from the egg to the adult may be found in both squares and bolls, even after frosts have occurred. The immature stages in squares are not immediately killed unless the freeze is exceptionally severe, but probably very few of these survive to reach maturity and to emerge during the following spring. Only those which are nearly adult at the time frost occurs may be expected to emerge. These might emerge upon warm days following the colder weather, but in the absence of a fresh food supply would soon die. In the fall of 1903 Prof. E. D. Sanderson records, from an examination of 700 squares at the middle

of November, finding 79 eggs, or that 11 per cent of the squares contained eggs. From an examination of 1,600 squares he states that 366 larvæ were found, showing that about 23 per cent of the squares contained larvæ at the time of entrance into hibernation. Some stages may survive in squares for a short time after the freeze, but there are few records of weevils entering hibernation at immature stages in squares and surviving to emerge therefrom in the spring. These stages are therefore unimportant from an economic point of view.

With immature stages entering hibernation in bolls (Pl. II, fig. 3) the case is quite different from that in squares. Extensive examinations have been made at various times in widely separated localities to determine the possibility of these stages maturing in the bolls during the winter and emerging in the spring. About the middle of November, in the winter of 1903–4, it was sufficiently cold at Victoria to destroy cotton plants. By the last week in December two hard frosts and one freeze had occurred, but at that time living larvæ, pupæ, and adults could be very commonly found in unopened bolls. Two weeks later, upon making another examination, Mr. J. D. Mitchell found a smaller proportion of larvæ with more pupæ and adults. Examinations were also made on January 17 and 31 and February 4 and 17, 1904. In the course of these examinations 23 larvæ, 30 pupæ, and 144 adults were found, and most of them were living. At Terrell, Tex., on December 15, 1904, in examinations of 200 bolls Mr. C. R. Jones found 101 larvæ, 16 pupæ, and 4 adults, all of which were alive. Fifteen days later, in examining 100 dry bolls, he found 20 larvæ, 16 pupæ, and 8 adults. Sixty per cent of the larvæ, 87.5 per cent of the pupæ, and 62.5 per cent of the adults were alive on December 30. On January 7, 1905, in an examination of 300 dried bolls 29 larvæ, 19 pupæ, and 13 adults were found, while the percentage of living, in each stage, had fallen to 17.2 for larvæ, 15.8 for pupæ, and 7.7 for adults. At Wharton, Tex., after the middle of November, 1905, an examination of 52 bolls disclosed 30 larvæ and 2 pupæ, all of which were alive.

These records might easily be multiplied, but it is unnecessary to do so to prove that very large numbers of weevils enter upon the period of hibernation as immature stages and that during many seasons, especially in the southern part of the State, a large percentage of these complete their development, and that many weevils may survive until time for their emergence in the spring. This point is emphasized especially because of its significance in regard to the most advisable method for destroying the stalks together with the infested unopened bolls which may remain upon them late in the season. Upon page 26 will be found records showing the results of extensive examinations of bolls during the winter and early spring, which add much emphasis to this point.

## TIME OF ENTERING HIBERNATION.

Before discussing the question of the time at which weevils usually "enter hibernation" it seems desirable to explain the sense in which that term is used. The action of the weevils in securing shelter from approaching cold is not intelligent. It is probably true that they have no such sense of sight as we commonly understand from the use of that word and that their selection of shelter is not at all guided by that sense. We mean by this that a weevil on a cotton plant can not see at any distance shelter which might be attractive to it and thereupon fly from the plant to the shelter. It is true that cold nights with a temperature between 40° and 50° F. succeeded by warm still days, such as occur commonly in the fall, do seem to stimulate the weevils to an unusual activity both in flight and in crawling. It may be true that they have an instinctive knowledge of the approach of temperature conditions from which they must secure shelter, but it is also true that many weevils remain active upon plants for some time after the plants have been destroyed by frost and frequently until several weeks after other individuals have entered hibernation. In speaking of entering hibernation, therefore, we mean the entrance of the weevils upon a period of comparative if not complete inactivity. Their action in securing shelter is gradual and governed primarily by the degree of protection from the cold which they may receive. If early in the season a weevil accidentally finds shelter which gives it exceptional protection from the cold it will likewise be exceptionally protected from heat, and therefore less likely than are other less fortunate individuals to resume its activity upon warm days. If at first the shelter which weevils find is but slight, they will be easily influenced by succeeding warmth, and in another period of activity will be likely to find better protection. Their flight upon warm days undoubtedly leaves large numbers of them outside of the cotton fields, where they are as likely to find favorable shelter as within the fields themselves.

From this explanation it will be understood that it is rarely possible to indicate by a single date the time when weevils enter hibernation. It may be better expressed as a period within the limits of which a large majority, though possibly not all, weevils may seek shelter. Naturally this time varies according to the seasonal temperature conditions, so that in one locality it may occur several weeks earlier in one season than in another. It is also evident that differences in temperature conditions due to latitude or altitude will cause a similar variation in the time when weevils enter hibernation. In the following paragraph are given the approximate dates which have been determined for this event at various localities since 1902.

At Victoria, Tex., large numbers of weevils were still active in the fields about the middle of December, 1902, at which time direct observations were discontinued. It is probable, however, that weevils were gradually seeking winter quarters at any time after the first of that month. Prof. E. D. Sanderson states that at College Station, Tex., in 1903 weevils did not enter hibernation until after a freeze which occurred on November 18. After this date they soon disappeared. In 1903, at Victoria, hibernation began between November 15 and 30. At several points between College Station and Terrell, Tex., in 1904, hibernation began about November 10 and was not complete until early in December. During this same year at Victoria it occurred during the period from November 11 to about December 8. The following year at Victoria it did not occur until after December 15, while in 1906 at the same place weevils entered hibernation between November 9 and 20. At Dallas, Tex., in 1905, few weevils entered hibernation before the end of November, when heavy frosts occurred, but they disappeared in the fields during the first few days of December. At Dallas in 1906 weevils entered hibernation between November 15 and December 1.

These conclusions as to the approximate periods when weevils entered hibernation are based upon field observations which showed the gradual disappearance of the weevils from the plants. The conclusions from field observations are supported, also, by those from cage experiments.

### PROPORTION OF EACH SEX AMONG WEEVILS IN FALL.

Determinations of sex proportion among weevils in midsummer have shown that during that period the sexes exist in approximately equal numbers. As the development becomes retarded by approaching cold weather there seems to be a tendency toward the production of more males than females. The generally longer life of males may also account in part for the increased proportion of that sex, which is shown in the following table:

TABLE I.—*Proportion of male and female weevils at time of entering hibernation.*

| Year. | Male. | | Female. | |
|---|---|---|---|---|
| | Number. | Per cent. | Number. | Per cent. |
| 1904 | 557 | 63.7 | 317 | 36.3 |
| 1905 | 63 | 57.7 | 127 | 42.3 |
| [illegible] | 173 | [illegible] | 78 | [illegible] |
| 1906 | 173 | [illegible] | 127 | [illegible] |
| 1906 | 19 | 57.6 | 14 | 42.4 |
| 1904 | 31 | 62.0 | 19 | 38.0 |
| 1906 | 29 | 52.7 | 26 | 47.3 |
| | 1,045 | 60.0 | 708 | 40.0 |

From this record it appears that at the time of entering hibernation male weevils largely predominate, being in the proportion approximately of 3 males to 2 females.

### NUMBER OF ADULT WEEVILS ENTERING HIBERNATION.

It is evident that determinations bearing upon the number of adult weevils entering hibernation must in all cases be largely in the form of estimates because of the physical impossibility of making a thorough examination of more than a comparatively small fraction of an acre. In our own determinations upon this point we have followed the general plan of selecting average crops of plants in four or five different portions of the field, representing, so far as may be possible, different conditions in the growth of the plants which may influence the number of weevils to be found. The number of plants per acre is ultimately the basis upon which the estimate as to the number of weevils per acre is based. It is evident that the number of plants will vary widely in different localities. For example, in the river valleys, where the growth of the plants is rank, the average number may be about 5,000; whereas upon poorer land, where plants never become large, the number per acre may be as great as 10,000. From estimates made upon several hundred fields during the past two years it appears that the average number of plants per acre is not far from 7,000. We believe that this method of estimating the number of weevils per acre is more desirable and reliable than an estimation of the number of weevils per plant in which the fractions found in an average must be disregarded.

In the fall of 1903 Prof. E. D. Sanderson found from his own observations and from reports of correspondents an average of from one to two weevils per plant. In the fall of 1904 an examination of four fields at Terrell, Tex., showed a variation of between 762 and over 29,000 weevils per acre. This wide variation was due primarily to the effect of defoliation by the cotton leaf-caterpillar in one field, that having the exceptionally large number of weevils not having been defoliated. These points are mentioned particularly to show the wide variation which may occur within very short distances and also to emphasize the effect of the work of the leaf-worm in accomplishing what is practically a more or less complete destruction of the stalks.

TABLE II.—*Counts to determine number of weevils per acre at time of entrance into hibernation, in three localities in Texas.*

| Date. | Locality. | Plants per acre. | Plants examined. | Weevils found. | Weevils per acre. | Remarks. |
|---|---|---|---|---|---|---|
| 1904. | | | | | | |
| Nov. 8 | Terrell | 10,890 | 100 | 267 | 29,076 | Not defoliated by leaf-worm. |
| Nov. 9 | do | 10,890 | 100 | 61 | 6,643 | Defoliated. |
| Nov. 10 | do | 10,890 | 70 | 5 | 762 | Do. |
| Nov. 14 | do | 10,890 | 50 | 7 | 1,742 | Do. |
| | Averages and totals. | 10,890 | 320 | 340 | 11,570 | Average four fields examined at Terrell. |
| Nov. 16 | Calvert | 7,260 | 30 | 4 | 968 | Defoliated. |
| Do. | do | 7,260 | 40 | 79 | 14,338 | Do. |
| Do. | do | 7,260 | 30 | 4 | 968 | Not defoliated. |
| Nov. 17 | do | 7,260 | 30 | 9 | 2,178 | Defoliated. |
| Do. | do | 7,260 | 30 | 39 | 9,438 | Defoliated once. |
| Do. | do | 7,260 | 30 | 4 | 900 | Do. |
| Nov. 18 | do | 7,260 | 50 | 21 | 3,049 | Defoliated. |
| | Averages and totals. | 7,260 | 240 | 160 | 4,840 | Average seven fields examined at Calvert. |
| 1905. | | | | | | |
| Nov. 14 | Wharton | 6,200 | 46 | 47 | 6,355 | Not defoliated. |
| Do. | do | 6,200 | 66 | 22 | 2,073 | Do. |
| Do. | do | 6,080 | 5 | 48 | 58,368 | Many squares. |
| Do. | do | 6,200 | 10 | 46 | 28,520 | Do. |
| Do. | do | 6,200 | 10 | 16 | 1,000 | Grazed by cattle. |
| Nov. 27 | do | 7,000 | 2 | 25 | 50,000 | Estimate reduced. |
| | Averages and totals. | 6,313 | 139 | 204 | 9,266 | Average six fields examined at Wharton. |

In connection with the work done at Dallas during the fall of 1906 repeated estimates of the number of weevils per acre to be found upon the stalks were made in the same field beginning October 12, 1906, and ending January 21, 1907. These figures are presented in Table III. The number of plants per acre in this field was 8,300.

TABLE III.—*Number of weevils per acre upon stalks at different dates at Dallas, Tex.*

| Date. | Plants examined. | Living weevils found. | Living weevils per acre. |
|---|---|---|---|
| 1906. | | | |
| Oct. 12 | 110 | 122 | 9,205 |
| Oct. 31 to Nov. 3 | 84 | 190 | 18,774 |
| Nov. 10 | 60 | 106 | 14,663 |
| Nov. 20 | 35 | 29 | 6,877 |
| Nov. 22 | 35 | 27 | 6,403 |
| Dec. 1 | 36 | 10 | 2,306 |
| Dec. 18 | 35 | 5 | 1,186 |
| 1907. | | | |
| Jan. 21 | 35 | 3 | 711 |

The table given above shows a number of points which are of exceptional interest. About November 1 it may be seen that the number of weevils present was more than double the number of plants. After that time there was found to be a steady decrease in the number of weevils present upon the stalks. The most abrupt change was to be found between November 10 and 20, when more than one-half

of the weevils seem to have left the plants. This decrease may be attributed to several factors. First, the weevils were gradually leaving the plants through flight, which may have carried them outside the fields, and, second, many were seeking and remaining in shelter which was to be found upon the ground within the field. A hard freeze preceded by low temperatures during several days occurred on November 19. However, the examinations made on November 20 and 22 showed many weevils present in the frozen squares and especially upon the bolls. It is apparent that these weevils did not immediately leave the plants, but remained upon the bolls and squares as long as the latter might serve as a food supply. But within a few days all squares and foliage became perfectly dry, and after this especially weevils became less active. The numbers which were found upon the plants after December 1 may be considered in a rather strict sense as in hibernation. The shelter which they could obtain was comparatively slight, and in the last examination, made on January 21, about 25 per cent of the weevils found upon the bolls still hanging to the stalks were dead.

In reference to Table II attention may be called to the exceptionally large number of weevils found at Wharton in one field on November 14. This was a field of about 5 acres in extent, and at the time it was examined the plants were exceptionally large and very luxuriant in growth, showing an abundance of squares. Very few bolls had been set, so that the entire growth of the plants seems to have been turned to the production of squares. As has been shown in preceding paragraphs, such conditions would favor directly the production of an abnormally large number of weevils per acre. The fact that more than 6,000 weevils were actually collected in this field makes it even more certain that the estimate given, while possibly high, is not impossible. It may be considered as representing fully the maximum number of weevils which it is possible for an acre of cotton to support even under conditions which are most favorable to their development. Another series of examinations made before and after the freeze referred to at Dallas in a preceding paragraph should be considered in connection with Table III as serving to show the correlation between the disappearance of the weevils from the plants and their occurrence under shelter on the ground during the period when they are entering hibernation.

TABLE IV.—*Number of weevils under rubbish on ground at Dallas, Tex.*

| Field. | Date examined. | Portion of acre examined. | Weevils found— | | Total per acre. | Percentage alive. | Remarks. |
|---|---|---|---|---|---|---|---|
| | | | Alive. | Dead. | | | |
| | 1906. | | | | | | |
| A | Nov. 15 | 22 plants. | 4 | 0 | 1,450 | 100.0 | In cracks of ground around bases of plants. |
| A | ...do..... | 1/264 | 4 | 0 | 1,056 | 100.0 | Under rubbish on ground. |
| A | Nov. 22 | 1/347 | 8 | 0 | 2,776 | 100.0 | Do. |
| A | Dec. 18 | 1/264 | 5 | 14 | 5,016 | 26.3 | Do. |
| | 1907. | | | | | | |
| B | Jan. 11 | 10/8384 | 5 | 2 | 5,870 | 71.4 | Northeast corner of field. |
| C | Jan. 29 | 10/6236 | 1 | 1 | 1,247 | 50.0 | Middle of field. |
| C | ...do..... | 10/8384 | 2 | 2 | 3,354 | 50.0 | Near southwestern edge. |

The sum total of weevils found both on plants and on the ground on November 22 shows an average of slightly more than 9,000 weevils per acre, all of which were alive. On December 18 the number that could be accounted for was between 6,000 and 7,000 per acre on the same ground which had been previously examined. On the former date more than two-thirds of the weevils were still upon the plants. On the latter date nearly five-sixths of them were on the ground and among those on the ground but 26 per cent were living. These figures show that between November 22 and December 18 a very large mortality had occurred among weevils which had entered hibernation and especially among those which had sought shelter under rubbish upon the surface of the black-waxy soil of field A.

There is some evidence indicating that there is normally a greater mortality among the weevils hibernating at the surface of heavy black soil than that occurring among weevils which hibernate on the surface of sandy soil. The reason for whatever difference there may really be in this mortality would seem to be quite directly attributable to the difference in drainage conditions in the two types of soil, and to the characteristic adhesiveness of the black type. It is quite likely that the difference is sufficient to justify different methods of treatment for the two classes, but our knowledge of the constant variations and the effective factors is not yet sufficiently complete to justify us in making specific recommendations.

### TEMPERATURE CONDITIONS PRODUCING HIBERNATION.

It is evident that the exact time at which weevils begin to enter hibernation, and that at which the entrance into hibernation becomes complete, can be determined only approximately. The evidence consists largely of observations showing the decrease in the number of weevils which are active, the finding of weevils in a quiet condition within various classes of shelter, the changes in activity of weevils confined in cages, the cessation of feeding and of reproductive

activity, and the general relationship of temperature to conditions of food supply and weevil activity. In the following tables are shown the maximum and minimum temperature occurring throughout the period, which has been approximately determined for each of the localities indicated in the respective seasons. The maximum temperature is given above and the minimum temperature below the line for each day. Wherever the climatic records for a particular locality are incomplete it has been necessary to use those for some other near-by locality. The table shows at a glance the daily range of temperature in each case, which undoubtedly has considerably more significance in regard to the entrance of weevils into hibernation than would the figures showing simply the mean daily temperature. The table as arranged shows a comparison of the records of all localities during each season successively.

TABLE V.—*Relation between time of entrance into hibernation and daily temperatures.*

| Year. | Locality. | Period of entering hibernation. | November— | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| 1903.. | College Station, Tex | Nov. 15–25 | | | | | | | 85 | 83 | 70 | 58 | 45 | 51 | 59 | 68 | 74 | 72 | 66 | 60 | 61 | | | |
| | | | | | | | | | 60 | 57 | 40 | 27 | 28 | 40 | 44 | 43 | 44 | 54 | 49 | 34 | 32 | | | |
| 1903.. | Victoria, Tex. *a* | Nov. 15–30 | | | | | | | 85 | 86 | 56 | 48 | 59 | 62 | 66 | 68 | 65 | 70 | 69 | 68 | 65 | 68 | 69 | 64 |
| | | | | | | | | | 50 | 52 | 45 | 32 | 32 | 36 | 39 | 42 | 45 | 45 | 52 | 38 | 33 | 38 | 37 | 39 |
| 1904.. | Terrell, Tex. *b* | Nov. 10–Dec. 5 | | 53 | 51 | 57 | 70 | 72 | 77 | 79 | 48 | 82 | 76 | 71 | 68 | 80 | 85 | 84 | 77 | 74 | 64 | 80 | 74 | 80 |
| | | | | 41 | 30 | 30 | 31 | 36 | 36 | 36 | 44 | 49 | 50 | 54 | 47 | 40 | 47 | 47 | 42 | 58 | 34 | 30 | 45 | 43 |
| 1904.. | Victoria, Tex. *c* | Nov. 11–Dec. 8 | | | 57 | 65 | 69 | 73 | 75 | 75 | 78 | 80 | 81 | 70 | 73 | 72 | 73 | 76 | 75 | 72 | 70 | 75 | 75 | 73 |
| | | | | | 42 | 32 | 36 | 37 | 38 | 40 | 42 | 48 | 51 | 61 | 58 | 55 | 53 | 50 | 50 | 51 | 47 | 42 | 45 | 46 |
| 1905.. | Dallas, Tex | Nov. 29–Dec. 8 | | | | | | | | | | | | | | | | | | | | | 52 | 40 |
| | | | | | | | | | | | | | | | | | | | | | | | 41 | 25 |
| 1905.. | Victoria, Tex | Nov. 30–Dec. 18 | | | | | | | | | | | | | | | | | | | | | | 55 |
| | | | | | | | | | | | | | | | | | | | | | | | | 41 |
| 1906.. | Dallas, Tex | Nov. 15–Dec. 8 | | | | 66 | 72 | 71 | 79 | 81 | 60 | 50 | 43 | 40 | 31 | 62 | 47 | 49 | 75 | 63 | 52 | 62 | 67 | 69 |
| | | | | | | 33 | 34 | 38 | 39 | 62 | 57 | 44 | 33 | 28 | 25 | 25 | 40 | 43 | 47 | 46 | 45 | 46 | 45 | 53 |
| 1906.. | Victoria, Tex | Nov. 9–Dec. 21 | 83 | 84 | 83 | 83 | 67 | 73 | 77 | 80 | 75 | 70 | 59 | 62 | 65 | 58 | 73 | 87 | 74 | 72 | 57 | 70 | 74 | 79 |
| | | | 58 | 54 | 59 | 54 | 59 | 47 | 41 | 54 | 46 | 57 | 35 | 27 | 33 | 50 | 50 | 60 | 59 | 55 | 56 | 54 | 53 | 60 |

| Year. | Locality. | Period of entering hibernation. | December | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 1904 | Terrell, Tex.[a] | Nov. 10–Dec. 5 | 85 | 80 | 52 | 43 | 48 | | | | | | | | | | | | | | | | |
| | | | 46 | 57 | 40 | 36 | 36 | | | | | | | | | | | | | | | | |
| 1904 | Victoria, Tex.[c] | Nov. 11–Dec. 8 | 77 | 83 | 65 | 53 | 47 | 52 | 65 | 67 | | | | | | | | | | | | | |
| | | | 55 | 61 | 45 | 43 | 40 | 40 | 36 | 45 | | | | | | | | | | | | | |
| 1905 | Dallas, Tex. | Nov. 29–Dec. 8 | 12 | 51 | 49 | 57 | 55 | 52 | 59 | 64 | | | | | | | | | | | | | |
| | | | 25 | 34 | 27 | 25 | 25 | 26 | 27 | 25 | | | | | | | | | | | | | |
| 1905 | Victoria, Tex. | Nov. 30–Dec. 18 | 57 | 66 | 51 | 57 | 59 | 51 | 61 | 67 | 67 | 60 | 51 | 61 | 58 | 60 | 63 | 60 | 65 | 65 | | | |
| | | | 49 | 44 | 35 | 31 | 37 | 42 | 42 | 45 | 48 | 40 | 39 | 46 | 46 | 44 | 35 | 35 | 54 | 46 | | | |
| 1906 | Dallas, Tex. | Nov. 15–Dec. 8 | 74 | 68 | 77 | 73 | 69 | 58 | 59 | 69 | | | | | | | | | | | | | |
| | | | 57 | 54 | 54 | 57 | 63 | 43 | 30 | 33 | | | | | | | | | | | | | |
| 1906 | Victoria, Tex. | Nov. 9–Dec. 21 | 80 | 79 | 82 | 83 | 83 | 79 | 71 | 80 | 81 | 73 | 65 | 72 | 80 | 78 | 65 | 49 | 46 | 45 | 47 | 54 | 75 |
| | | | 62 | 63 | 62 | 65 | 58 | 44 | 48 | 63 | 65 | 46 | 45 | 60 | 63 | 68 | 41 | 39 | 40 | 32 | 33 | 33 | 36 |

[a] Cuero, Tex., records.

[b] Corsicana, Tex., records.

[c] November records for Cuero; December records for Victoria, Tex.

This table serves to show in a graphic way the extent of the period of entrance into hibernation, the varying duration of the period for the same locality in different seasons, and the generally later date of entrance in southern localities as compared with more northern localities in the same season. It also shows the duration of the period as compared with the mean average temperature prevailing. In general it appears that the greater the drop in temperature the shorter will be the period of entrance into hibernation.

TABLE VI.—*Periods of entrance into hibernation, and temperatures.*

| Year. | Locality. | Period. | | Temperature. | |
|---|---|---|---|---|---|
| | | Limits. | Days. | Mean average. | Effective.[a] |
| 1903 | College Station, Tex | Nov. 15–27 | 13 | 49.5 | 6.5 |
| 1903 | Victoria, Tex | Nov. 15–30 | 16 | 53.0 | 10.0 |
| 1904 | Corsicana, Tex | Nov. 10–Dec. 5 | 26 | 55.0 | 12.0 |
| 1904 | Victoria, Tex | Nov. 11–Dec. 8 | 28 | 57.5 | 14.5 |
| 1905 | Dallas, Tex | Nov. 29–Dec. 8 | 10 | 40.5 | None. |
| 1905 | Victoria, Tex | Nov. 30–Dec. 18 | 19 | 50.0 | 7.0 |
| 1906 | Dallas, Tex | Nov. 12–Dec. 8 | 27 | 53.0 | 10.0 |
| 1906 | Victoria, Tex | Nov. 9–Dec. 21 | 43 | 60.4 | 17.4 |

[a] In studying the relationship of temperature conditions to weevil activity the term "effective temperature" is used to designate the excess of temperature above 43 degrees F. It has been estimated that 43 degrees marks approximately the beginning of activity with most animals, and experiments have shown that this is equally true of the boll weevil. Below this temperature the weevils are usually inactive. Above it they may move, feed, and reproduce with increasing rapidity as the temperature increases. From this explanation it may be readily understood that the column showing the decrease of effective temperature is really the most significant in connection with the inactivity or hibernation of the weevil.

It is undoubtedly true that minimum temperatures have a special influence in checking the activity of the weevil in spite of the fact that they may be below 43 degrees F. When the temperature falls to 32 degrees or lower the food supply of the weevils is usually rather completely destroyed, and this fact may serve to discourage subsequent activity on the part of the weevils, even though the temperature conditions might otherwise favor it.

From this table it may be seen that the shortest period of entrance into hibernation of which we have record is ten days. This occurred at Dallas, when the mean average temperature was 9 degrees lower than that for any other period which has been studied.

In regard to the limits assigned to the period for Victoria in 1906 it may be stated that hibernation was probably only partial at that place at any time during the winter of 1906–7. The limits of the period that have been given are based on field notes made about the middle of November indicating the beginning of the period, and temperature records covering the coldest period that occurred during December. The mean average temperature during November for Victoria was 60.4 degrees, the range being from an absolute minimum of 27 degrees to an absolute maximum of 84 degrees. The temperature

fell below 32 degrees only once during this month. From December 1 to 21 the mean average temperature was also 60.4 degrees. In this case the range of temperature varies from an absolute maximum of 83 degrees to an absolute minimum of 32 degrees, the latter occurring only once. From these records it is apparent that the climatic conditions were not sufficiently severe either to destroy absolutely the food supply of the weevils or to insure the continued inactivity of those which may have sought shelter during the short periods of cool weather. Sprout cotton was exceptionally abundant throughout the winter and weevils were found feeding upon it almost continuously.

From these facts we may be justified in concluding that a mean average temperature of 60 degrees is too high for the complete hibernation of the weevil; that hibernation usually takes place coincidently with the decrease in mean average temperature to about 55 degrees; and that it remains complete until the mean average temperature subsequently rises to above 60 degrees.

## SHELTER DURING HIBERNATION.

While many weevils seek hibernation shelter outside the field it is certain that a considerable number of them remain very near their food supply—that is, in the cotton fields and in the immediate vicinity. Because of the differences in the nature of the weevil shelter and in the possibility of destroying or removing such favorable shelter, within and without the cotton fields, these two conditions will be considered separately.

### SHELTER IN BOLLS.

Within the cotton fields weevils are sheltered primarily in the hanging cotton bolls, the fallen foliage, and grass or other rubbish which may have accumulated upon the surface of the ground. Attention has already been called to the fact that many stages enter the period of hibernation in an immature condition in unopened bolls. (See p. 14.) That many adult weevils hibernate entirely within the protection afforded by the bracts and hulls of bolls has been abundantly demonstrated (Pl. II, fig. 3). Rather extensive experiments have been made upon this point in a number of localities during several seasons. The principal data resulting from these investigations are presented in the following two tables. Table VII shows a comparison of the records for several localities during four months of the winter of 1904–5. During this period the prevailing climatic conditions were the most severe that the weevil has encountered since invading Texas. The table shows therefore a gradual decrease in the number of living stages present as the season advanced.

TABLE VII.—*Decrease in percentage of stages surviving in bolls from December, 1904, to March, 1905.*

| Locality. | December. | | | | | | | | January. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Stages alive. | | | | | | | | Stages alive. | | | | | |
| | | | | Adults. | | | | | | | | Adults. | | | |
| | Bolls examined. | Larvæ. | Pupæ. | Not emerged.[a] | Emerged.[a] | Bolls having living forms. | Forms found living. | | Bolls examined. | Larvæ. | Pupæ. | Not emerged.[a] | Emerged.[a] | Bolls having living forms. | Forms found living. |
| | | | | | | *P. ct.* | *P. ct.* | | | | | | | *Per ct.* | *Per ct.* |
| Terrell, Tex. | 300 | 113 | 30 | 9 | 0 | 48 | 92 | | 3,678 | 38 | 16 | 3 | 6 | 1.98 | 7.3 |
| Keatchie, La. | | | | | | | | | 1,120 | 3 | 0 | 2 | 3 | .70 | 26.0 |
| Dallas, Tex. | | | | | | | | | | | | | | | |
| Calvert, Tex. | 150 | 10 | 1 | 0 | 0 | 7 | 91 | | 2,100 | 0 | 1 | 1 | 10 | .50 | 10.0 |
| Palestine, Tex. | | | | | | | | | | | | | | | |
| Victoria, Tex. | | | | | | | | | 3,257 | 11 | 7 | 9 | 18 | 1.37 | 61.0 |
| Totals and averages. | 450 | 123 | 31 | 9 | 0 | 36 | 91 | | 10,155 | 52 | 24 | 15 | 37 | 1.15 | 11.8 |

| Locality. | February. | | | | | | | March. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Stages alive. | | | | | | | Stages alive. | | | | | |
| | | | | Adults. | | | | | | | Adults. | | | |
| | Bolls examined. | Larvæ. | Pupæ. | Not emerged.[a] | Emerged.[a] | Bolls having living forms. | Forms found living. | Bolls examined. | Larvæ. | Pupæ. | Not emerged.[a] | Emerged.[a] | Bolls having living forms. | Forms found living. |
| | | | | | | *Per ct.* | *Per ct.* | | | | | | *Per ct.* | *Per ct.* |
| Terrell, Tex. | 1,500 | 2 | 2 | 0 | 0 | 0.26 | 1.5 | | | | | | | |
| Keatchie, La. | 1,450 | 2 | 2 | 1 | 0 | .34 | 15 | 208 | 0 | 0 | 0 | 0 | 0 | 0 |
| Dallas, Tex. | | | | | | | | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| Calvert, Tex. | 800 | 0 | 0 | 0 | 0 | 0 | 0 | 2,176 | 0 | 0 | 0 | 0 | 0 | 0 |
| Palestine, Tex. | | | | | | | | 1,599 | 0 | 0 | 0 | 0 | 0 | 0 |
| Victoria, Tex. | 2,746 | 4 | 0 | 3 | 3 | .36 | 8.6 | 1,438 | 0 | (1) | 0 | 0 | 0 | 0 |
| Totals and averages. | 6,496 | 8 | 4 | 4 | 3 | .29 | 4.1 | 5,521 | 0 | 1 | 0 | 0 | 0 | 0 |

[a] In Tables VII and IX the designation "not emerged" is used for those stages and adults which have not left the cells in which they developed. Adults which have previously left the cells within which they matured and have subsequently sought shelter within any part of the bolls are designated as "emerged."

Besides showing that large numbers of weevils entered hibernation in or upon these bolls, this table shows that bolls do not provide sufficient shelter to insure the survival of hibernating weevils in a winter so severe as was that of 1904–5.

TABLE VIII.—*Climatic conditions at Dallas, Calvert, Palestine, and Victoria, Tex., and at Keatchie, La., December 1, 1904, to March 31, 1905, producing complete mortality of weevils hibernating in bolls.*

DECEMBER, 1904.

| Locality. | Temperature. | | | | | Rainfall. | |
|---|---|---|---|---|---|---|---|
| | Times below 32° F. | Absolute minimum. | Average minimum. | Monthly mean. | Departure from normal. | Depth. | Departure from normal. |
| | | °F. | °F. | °F. | °F. | *Inches.* | *Inches.* |
| Dallas, Tex | 15 | 20 | 33.1 | 46.6 | − 1.2 | 0.74 | −1.40 |
| Keatchie, La.[a] | 6 | 22 | 39.4 | 48.9 | − .5 | 9.62 | +4.94 |
| Calvert, Tex.[b] | 14 | 21 | 37.6 | 50.0 | + .1 | 2.58 | − .04 |
| Palestine, Tex | 5 | 22 | 40.1 | 49.6 | − 1.8 | 4.08 | + .27 |
| Victoria, Tex | 5 | 30 | 44.1 | 54.8 | − 3.0 | 1.59 | − .26 |
| Average | 9 | ..... | 38.8 | 50.0 | − 1.3 | 3.70 | + .702 |

JANUARY, 1905.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Dallas, Tex | 24 | 12 | 27.8 | 38.7 | − 6.2 | 3.05 | +0.33 |
| Keatchie, La.[a] | 12 | 17 | 33.6 | 41.0 | − 4.9 | 4.13 | − .47 |
| Calvert, Tex.[b] | 13 | 16 | 34.1 | 44.8 | − 3.1 | 2.01 | − .14 |
| Palestine, Tex | 11 | 18 | 34.7 | 43.0 | − 2.8 | 2.06 | −2.25 |
| Victoria, Tex | 6 | 25 | 43.1 | 53.0 | − .6 | 3.84 | +1.11 |
| Average | 13 | ..... | 34.66 | 44.1 | − 3.52 | 3.02 | − .284 |

FEBRUARY, 1905.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Dallas, Tex | 30 | 2 | 24.6 | 35.2 | − 9.4 | 2.81 | +1.11 |
| Keatchie, La.[a] | 19 | 6 | 31.4 | 39.4 | −11.8 | 4.12 | − .04 |
| Calvert, Tex.[b] | 21 | 10 | 28.2 | 39.2 | −10.7 | 3.02 | +1.20 |
| Palestine, Tex | 21 | 6 | 31.9 | 40.0 | −11.0 | 2.47 | −1.00 |
| Victoria, Tex | 10 | 20 | 34.7 | 44.1 | − 9.9 | 3.62 | +1.42 |
| Average | 20 | 8.8 | 30.2 | 39.6 | −10.6 | 3.21 | + .59 |

MARCH, 1905.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Dallas, Tex | 0 | 35 | 47.1 | 59.6 | + 4.0 | 4.44 | +1.29 |
| Keatchie, La.[a] | 0 | 42 | 53.5 | 62.6 | + 5.0 | 5.03 | + .39 |
| Calvert, Tex.[b] | 0 | 35 | 51.6 | 62.1 | + 4.4 | 4.95 | +2.34 |
| Palestine, Tex | 0 | 37 | 53.7 | 62.4 | + 2.5 | 3.95 | + .14 |
| Victoria, Tex | 0 | 46 | 57.2 | 65.8 | + 3.1 | 5.04 | +3.52 |
| Average | 0 | ..... | 52.6 | 62.5 | + 3.8 | 4.68 | +1.54 |

[a] Temperatures for Shreveport, La. [b] Temperatures for Hearne, Tex.

An examination of this table shows that the temperature went below freezing with remarkable frequency during this period. The most severe cold weather occurred during February, when the temperature averaged 10 degrees or more below normal throughout the State of Texas. The absolute minimum for this season at the five points mentioned is recorded by the Weather Bureau as being 2 degrees above zero at Dallas. At Calvert the minimum temperature was 10 degrees and at Victoria 20 degrees. In most of the localities there was an excess of rainfall, so that the winter as a whole may be characterized as having been unusually cold and wet.

While these records show that few if any weevils survived in the shelter of bolls during this season it must be remembered that the weevils were not exterminated in all of these localities. Other conditions of shelter were evidently so much more favorable than bolls as to have enabled the weevils to survive this severe winter. It is true, however, that in the spring of 1905 weevils occurred in much smaller numbers than is usually the case.

Other examinations of bolls show that in the northern portion of the infested area of Texas there is a smaller percentage of living stages in the bolls than in the southern portion. The data for three seasons are compared in Table IX. The periods selected are during the last of the winter season in each year.

TABLE IX.—*Increase in percentage of survival in bolls from northern to southern Texas.*

| Section. | March, 1904. | | | | | | | February and March, 1905. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bolls examined. | Stages alive. | | | | Bolls having living forms. | Living forms. | Bolls examined. | Stages alive. | | | | Bolls having living forms. | Living forms. |
| | | Larvæ. | Pupæ. | Adults. | | | | | Larvæ. | Pupæ. | Adults. | | | |
| | | | | Not emerged. | Emerged. | | | | | | Not emerged. | Emerged. | | |
| | | | | | | *Per ct.* | *Per ct.* | | | | | | *Per ct.* | *Per ct.* |
| Northern | 2,600 | 0 | 0 | 0 | 0 | 0 | 0 | 3,258 | 4 | 4 | 1 | 0 | 0.27 | 0.026 |
| Central | 180 | 0 | 0 | 0 | 1 | 0.55 | ..... | 4,575 | 0 | 0 | 0 | 0 | .00 | .000 |
| Southern | 250 | 0 | 0 | 23 | 28 | ..... | ..... | 9,589 | 4 | 1 | 4 | 14 | .24 | .096 |
| Brownsville | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 809 | 0 | 0 | 4 | 11 | 1.80 | .833 |

| Section. | February and March, 1906. | | | | | | | Total. | |
|---|---|---|---|---|---|---|---|---|---|
| | Bolls examined. | Stages alive. | | | | Bolls having living forms. | Living forms. | Bolls examined. | Stages found alive. |
| | | Larvæ. | Pupæ. | Adults. | | | | | |
| | | | | Not emerged. | Emerged. | | | | |
| | | | | | | *Per ct.* | *Per ct.* | | |
| Northern | 6,186 | 0 | 0 | 1 | 2 | 0.04 | 0 | 12,044 | 12 |
| Central | 6,650 | 0 | 0 | 5 | 11 | .24 | 0 | 11,405 | 17 |
| Southern | 1,410 | 0 | 0 | 1 | 10 | .78 | 0 | 11,249 | 85 |
| Brownsville | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 809 | 15 |

It is noticeable that there is a gradual increase in the living stages from north to south, and that toward the end of the hibernation period nearly all of the living stages are adults, most of which had matured before the beginning of hibernation.

That the increased mortality found in bolls during the winter of 1904–5 can not be attributed entirely to the exceptional severity of that season is shown by the fact that a similar decrease in the per-

centage of living stages was found in examinations during January and February of 1906. In January among 1,933 bolls examined in several localities 86 adults and stages were found. In February 14,246 bolls were examined and only 30 adults were found. The lowest temperature experienced during January was 12° F. at Dallas, with the mean temperature of 49.6° F. in an average of the eight localities where the examinations were made. During February the absolute minimum was 15° F. at Dallas and the average minimum 38.5° F. During these two months in the localities where examinations were made the minimum temperature went below 32 degrees on an average of only nineteen days.

TABLE X.—*Climatic conditions at eight points in Texas, January to March, 1906.*

JANUARY.

| Locality. | Temperature. | | | | | Precipitation. | |
|---|---|---|---|---|---|---|---|
| | Times below 32° F. | Absolute minimum. | Average minimum. | Monthly mean. | Departure from normal. | Depth. | Departure from normal. |
| | | °F. | °F. | °F. | °F. | *Inches.* | *Inches.* |
| Dallas | 18 | 12 | 30.8 | 44.4 | −0.5 | 1.98 | −0.74 |
| Corsicana | 12 | 19 | 35.4 | 48.6 | +1.7 | 1.97 | − .67 |
| Hearne | 15 | 21 | 36.6 | 49.9 | +2.0 | .81 | −1.65 |
| Palestine | 10 | 21 | 39.2 | 49.6 | +3.8 | 1.92 | −2.39 |
| Waco | 11 | 22 | 36.0 | 51.2 | +3.1 | 1.38 | − .55 |
| Nacogdoches | 16 | 19 | 34.9 | 47.4 | − .8 | 4.85 | +2.11 |
| Austin | 3 | 26 | 41.6 | 51.4 | +2.7 | .81 | −1.67 |
| Victoria | 3 | 25 | 42.1 | 54 4 | + .8 | 1.34 | −1.09 |
| Average | 11 | ..... | 37.1 | 49.6 | +1.6 | 1.88 | − .83 |

FEBRUARY.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Dallas | 12 | 15 | 32.6 | 46.0 | +1.4 | 2.23 | +0.53 |
| Corsicana | 9 | 19 | 37.1 | 58.0 | +1.9 | 2.61 | + .49 |
| Hearne | 7 | 23 | 37.2 | 49.4 | − .5 | 4.22 | +2.40 |
| Palestine | 7 | 22 | 38.7 | 48.6 | −2.4 | 3.06 | − .45 |
| Waco | 8 | 20 | 37.3 | 50.8 | − .8 | 2.65 | + .72 |
| Nacogdoches | 10 | 20 | 36.7 | 48.2 | − .4 | 1.73 | −2.09 |
| Austin | 6 | 26 | 43.9 | 52.1 | − .6 | 1.29 | − .59 |
| Victoria | 5 | 28 | 44.3 | 54.4 | + .4 | 2.01 | + .19 |
| Average | 8 | ..... | 38.5 | 51.0 | − .12 | 2.48 | + .15 |

MARCH.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Dallas | 11 | 25 | 38.9 | 50.8 | −4.8 | 3.24 | +0.09 |
| Corsicana | 5 | 27 | 39.7 | 49.9 | −7.6 | 2.10 | −1.25 |
| Hearne | 2 | 26 | 43.4 | 55.4 | −2.3 | 1.97 | − .64 |
| Palestine | 2 | 28 | 44.1 | 53.4 | −4.2 | 1.24 | −2.74 |
| Waco | 3 | 27 | 43.2 | 57.5 | −1.1 | 2.95 | − .09 |
| Nacogdoches | 3 | 27 | 44.0 | 54.3 | −3.2 | 1.63 | −2.82 |
| Austin | 1 | 32 | 47.8 | 56.8 | −3.4 | 2.47 | + .25 |
| Victoria | 1 | 31 | 50.5 | 61.0 | −1.7 | 2.24 | + .72 |
| Average | 3.5 | ..... | 44.0 | 55.0 | −3.54 | 2.23 | − .94 |

A comparison of the principal points shown in Tables VIII and X indicates the relative severity of the two seasons, especially in the columns showing absolute minimum and average minimum

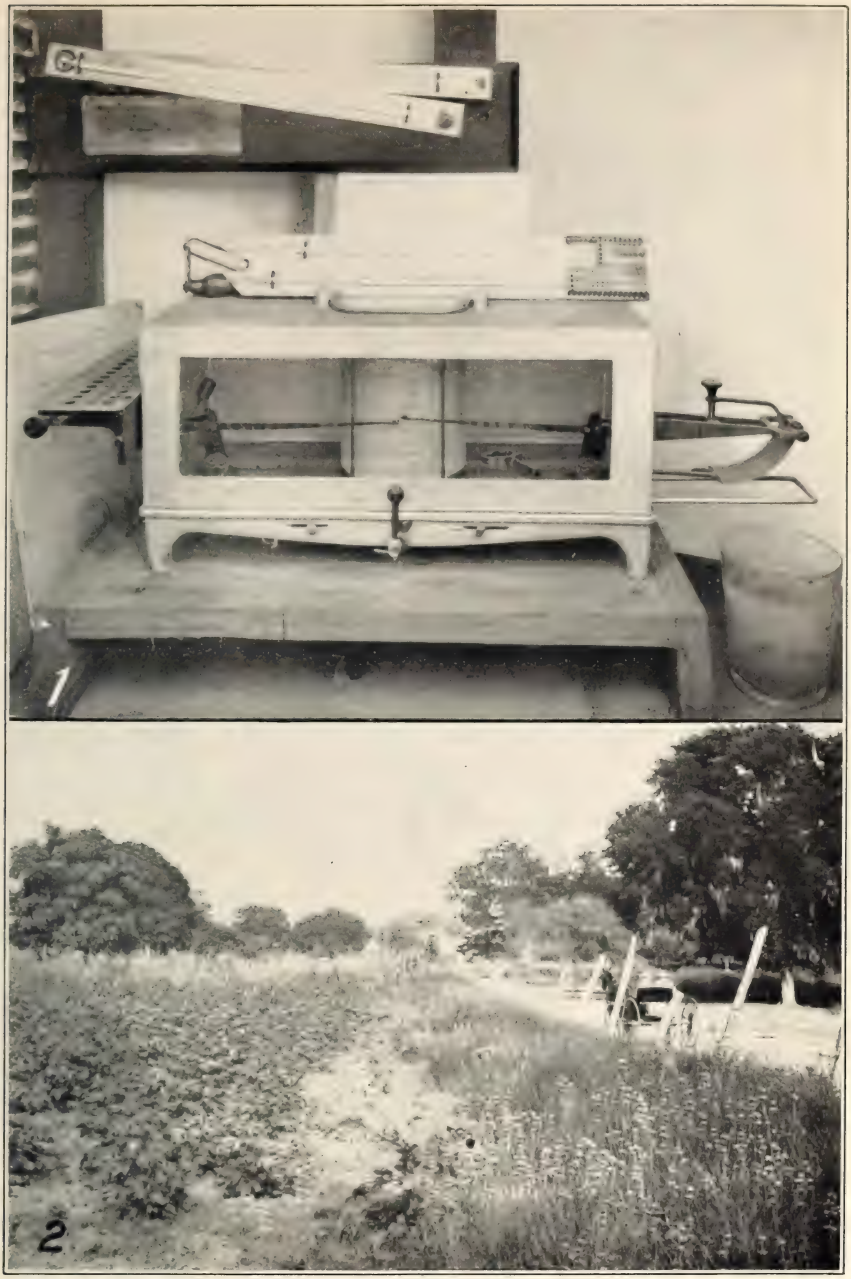
temperatures and departures from normal. The records for February are especially significant. In 1905 this month was unusually cold throughout the State. The absolute minimum for the five localities considered in that year was 2° F. at Dallas and the average minimum was 8.3° F. below that occurring in 1906. In 1905 the mean average temperature for the month was 10.6° F. below the normal while in 1906 it was but 0.12° F. below normal. It was during this month of extreme cold with excessive rainfall in 1905 that the greatest mortality among weevil stages occurred.

### HIBERNATION SHELTER OTHER THAN BOLLS WITHIN THE FIELD.

During an ordinary season it can not be doubted that a large majority of the weevils which survive find some other shelter than the bolls hanging upon the plants. It is not, however, as easy a matter to find weevils in rubbish scattered upon the ground as in bolls. It is necessary to collect the rubbish very carefully and sift it over cloth or paper to separate the weevils from the trash. In this way it has been found that weevils hibernate extensively in the leaf and grass rubbish distributed throughout the field. Naturally the cleaner the field in the fall the smaller will be their chances of finding favorable shelter during the winter.

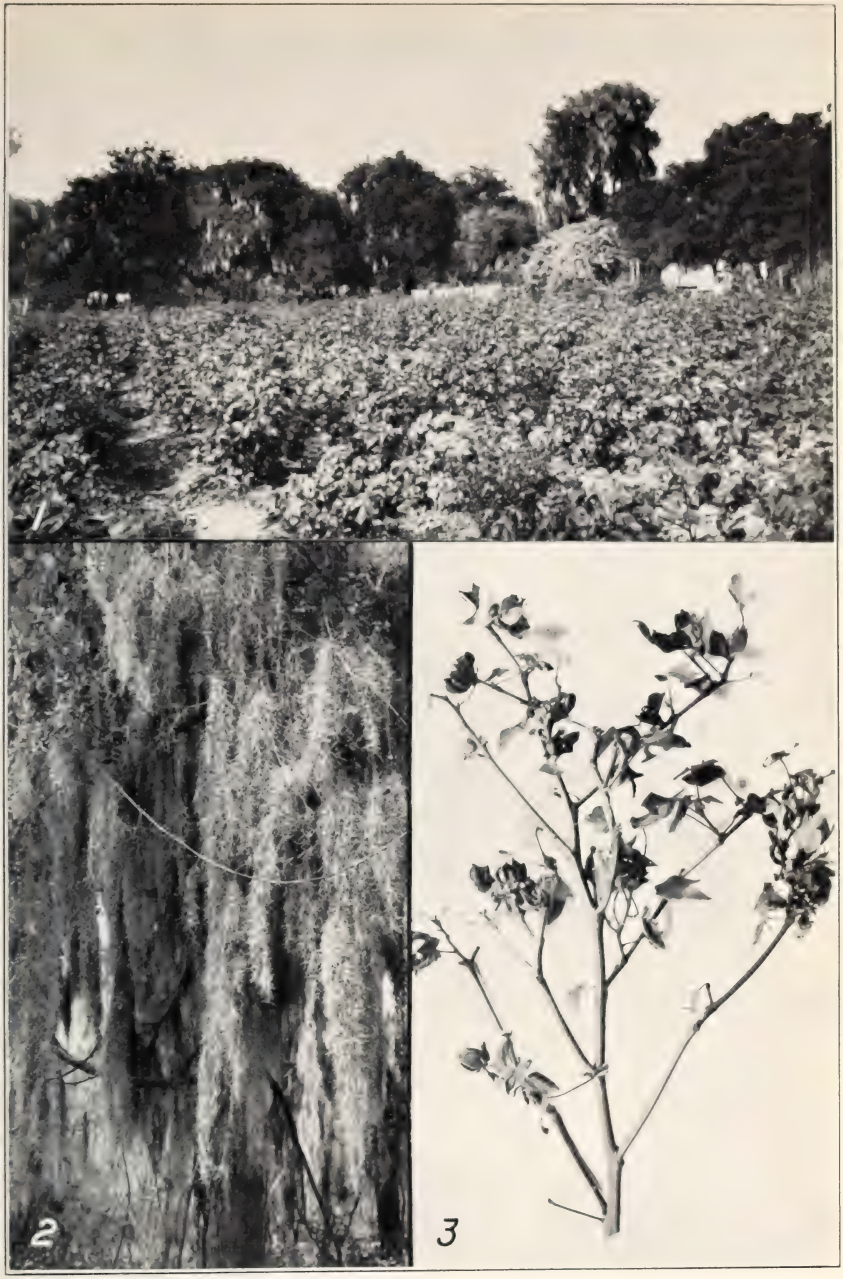
Standing trees are a common sight in cotton fields, and while the records of weevils found hibernating under bark are but few they are sufficient to indicate that these trees may be a rather important factor where they occur in considerable numbers. Where the Spanish moss (*Tillandsia usneoides*) (Pl. II, fig. 1) occurs, as in the bottom lands in the coast section of Texas and in the southern portions of the Gulf States, weevils find exceptionally favorable shelter within this moss. On January 18 Mr. J. D. Mitchell cut down a moss-covered tree growing in a large cotton field in the vicinity of Victoria, Tex. Between 400 and 500 pounds of moss growing on this tree was collected and examined very carefully. Three living specimens of the boll weevil were found. On February 5, 1907, a similar experiment was tried. One thousand pounds of moss was obtained from a tree standing in the midst of cotton fields. The moss was situated from 7 to 15 feet above the ground. Among a large number of other insects found hibernating in the moss there were ten living boll weevils. The weevils seem to prefer the festoons of green hanging moss to the bunches of dead matted moss (Pl. II, fig. 2).

The turnrows and ditches throughout the fields and the fence rows (Pl. I, fig. 2) surrounding them present exceptionally favorable conditions for successful hibernation. It has been noticed frequently that early in the season the most severe injury may occur on the edge of a field adjoining a fence row where weeds and grass abound.




WEATHER-RECORDING APPARATUS AND FENCE-ROW SHELTER.

Fig. 1.—Weather apparatus used in recording temperature and humidity conditions. Fig. 2.—Typical weedy fence row, affording excellent shelter for weevils. (Original.)




FAVORABLE SHELTER CONDITIONS IN AND AROUND FIELDS.

Fig. 1.—Cotton field adjoining grove of trees laden with Spanish moss (*Tillandsia usneoides*). Fig. 2.—Near view of moss. Fig. 3.—Cotton stalk having many bolls infested by weevils at hibernation time. (Original.)

One fact should be emphasized in regard to practically all classes of shelter which have been mentioned as occurring within cotton fields, i. e., that it is possible as a rule to destroy or remove practically all of them. Undoubtedly the burning of cotton stalks, weeds, grass, and other rubbish is the easiest and most effective method of destruction where it can be practiced. Next to this in importance would be the destruction of the stalks by a stalk chopper and plowing under all the rubbish. In the latter case it must be stated that many weevils which may be buried to an average depth of 2 inches will be able to escape through the soil and may then find shelter around, if not within, the field.

### HIBERNATION SHELTER OUTSIDE OF COTTON FIELDS.

Unquestionably timber fringes skirting cotton fields are exceedingly important because of the shelter which the fallen leaves and undergrowth provide for weevils during the winter. The conditions to be found here are so exceedingly favorable that a majority of planters seem to recognize that the most severe infestation of young cotton in the spring may be expected to occur near such timber. Where the moss (Pl. II, fig. 1) occurs abundantly it is second only in importance to the fallen leaves as a shelter for weevils. The fact that weevils have been taken early in the spring upon trees at a distance as great as 2 miles from a cotton field shows the extent to which they may possibly scatter during the fall or seek for cotton during the spring. The planter need not, however, be alarmed by these facts, inasmuch as it is certain that but few weevils hibernating away from the immediate vicinity of cotton fields will survive to find food supply upon emergence.

Cornfields adjoining cotton or cornstalks scattered throughout cotton fields may shelter many weevils. This was first noticed by Mr. E. A. Schwarz at Victoria in the winter of 1901–2 and has since been corroborated by a number of observers. Several examinations have been made of haystacks in the vicinity of cotton. This is a task quite comparable with that of seeking for the proverbial needle and it is not surprising that the results have been very meager. The fact, however, that traces of weevils have been found in these examinations indicates that weevils may find shelter under such conditions.

Farmyards, seed houses, barns, ginneries, and oil mills also afford exceptionally favorable shelter for weevils. Especially in ginneries and seed houses (Pl. III, fig. 1) the weevils become concentrated with the concentration of the cotton or seed and frequently may be found in large numbers within or around these buildings. In connection with this subject the reader is referred to a fuller discus-

sion of the significance of gineries and oil mills in the distribution of weevils and of the methods recommended for controlling them which may be found in Farmers' Bulletin No. 209 of the Department of Agriculture, "Controlling the Cotton Boll Weevil in Cotton Seed and at Ginneries." Numerous observations have shown that weevils have been taken into new localities through the agency of shipments of cotton seed and cotton-seed hulls from ginneries and oil mills handling infested stock. Definite observations have been made showing that living weevils may occur in cotton seed at planting time. While it is probable that few would survive in a large mass of seed it is certain that some might do so and be distributed in the planting of the seed.

TABLE XI.—*Experiments of 1904 to 1906 to test hibernation in cotton seed.*

| Locality. | When put in hibernation. | Weevils put in hibernation. | When examined. | Weevils found alive. | Weevils found dead. |
|---|---|---|---|---|---|
| | 1904. | | 1905. | | |
| Terrell, Tex. | Nov. 13 | 200 | Apr. 20 | 0 | 154 |
| Do. | Nov. 30 | 200 | Apr. 21 | 0 | 139 |
| Do. | Dec. 15 | 250 | Apr. 22 | 0 | 170 |
| Corsicana, Tex. | Nov. 14 | 150 | Apr. 19 | 0 | 127 |
| Calvert, Tex. | Nov. 15 | 200 | Apr. 7 | 0 | 152 |
| Do. | Nov. 30 | 200 | Apr. 8 | 0 | 176 |
| Do. | Dec. 15 | 200 | do. | 0 | 142 |
| Victoria, Tex. | Nov. 10 | 200 | Apr. 3 | 0 | 130 |
| Do. | Nov. 17 | 200 | do. | 0 | 144 |
| Do. | Nov. 25 | 200 | Apr. 1 | 0 | 150 |
| Do. | Dec. 1 | 200 | Mar. 31 | 0 | 115 |
| Do. | Dec. 8 | 200 | Mar. 29 | 1 | 149 |
| Do. | Dec. 15 | 200 | Mar. 28 | 1 | 123 |
| Total. | | 2,600 | | [a]2 | 1,871 |
| | 1905. | | 1906. | | |
| Dallas, Tex. | Nov. 1 | 100 | Apr. 28 | 0 | 92 |
| Do. | Nov. 18 | 200 | Apr. 30 | 0 | 160 |
| Do. | Dec. 4 | 200 | May 3 | 0 | 181 |
| Do. | Dec. 15 | 900 | May 4 | 0 | 862 |
| Total. | | 1,400 | | 0 | 1,295 |
| Victoria, Tex. | Nov. 7 | 100 | Apr. 2 | 0 | 93 |
| Do. | do. | 100 | Apr. 7 | 0 | 93 |
| Do. | Nov. 13 | 100 | Apr. 3 | 0 | 97 |
| Do. | Nov. 30 | 100 | do. | 0 | 100 |
| Do. | Dec. 11 | 100 | Apr. 5 | 0 | 96 |
| Total. | | 500 | | 0 | 479 |

[a] On January 27 47 dead and 18 living weevils were removed, and on March 4 4 dead and 1 living weevils were removed.

While the number and percentage of weevils surviving in these experiments is very small indeed, the fact that some do survive is the special point having significance. The occasional occurrence up to planting time of living weevils among seed from infested localities is alone sufficient justification for every quarantine restriction which has been placed upon cotton seed and other cotton products by uninfested territory.

The Mexican entomologist Prof. L. de la Barreda, under the direction of Prof. A. L. Herrera, of the Comisión de Parasitologia Agrícola,

has made some very pertinent observations on the occurrence of boll weevils in cotton seed intended for planting.[a] In January, 1903, this entomologist examined a number of sacks of seed received from the infested area of Texas for planting in the Laguna region in Mexico. Six sacks from one consignment were selected. In these, 12 living weevils were found, together with 56 dead ones. Later examinations were made of a number of shipments of seed from the infested portions of the United States. In every case living weevils were found. This work was done in the month of January. These observations show clearly the real danger that exists in the shipment of cotton seed from infested localities to those where the weevil does not occur.

## HIBERNATION EXPERIMENTS IN SMALL CAGES.

In many ways it is possible to obtain more accurate data upon hibernation of weevils through cage experiments than through field observations. In the cages conditions may be prepared which are typical of those to be found in the fields. The number of weevils within a given space can be largely increased without overcrowding, so far as the possibility of their finding shelter is concerned. The action of the weevils in seeking and in leaving shelter can be determined more accurately in cages than in the field. The food conditions may be varied to represent various field conditions and, finally, knowing definitely the number of weevils placed under certain conditions, it is possible to follow them closely enough to determine with a great deal of accuracy the proportions surviving. From a comparison of the results obtained under various experimental conditions those conditions which are most favorable as well as those which are least favorable to successful hibernation may be determined with considerable certainty. In all of our experimental work of this nature the cage results have been checked so far as has been possible by field observations.

With the continued study of the boll-weevil problem the necessity for increasingly comprehensive experiments upon hibernation has become apparent. The work thus shows from year to year a growth in complexity with the constant purpose of increasing the accuracy of results by making the experimental conditions conform as closely as is possible to field conditions. In the early stages of the work the hibernation cages were small and portable. Some were placed out of doors where they would be fully exposed to prevailing climatic conditions; others were placed in the shelter of buildings or under similar conditions where the favorable nature of the shelter provided might be determined.

[a] Boletín de la Comisión de Parasitologia Agrícola, vol. 2, No. 2, pp. 45 to 61.

### CAGE EXPERIMENTS OF 1902–3.

In the experiments made during the season of 1902–3 most of the weevils used were collected in the field at Victoria, Tex., about the middle of December. Some, however, were reared weevils which during the months of September and October previous had become adult. They were confined in boxes and jars covered with cheese cloth. Various kinds of rubbish were placed in the cages, some of which were placed in the fields and some in a building.

These cages were all examined between April 15 and 30, 1903. Among the 25 lots tested, including 356 weevils, it was found that an average of about 11 per cent had survived. None of those which were adult before November 1 was living on April 15, while nearly 16 per cent of those taken in the field about the middle of December were still alive on April 27. A slightly higher percentage had survived in the inside tests, and it appears that a considerable degree of dryness favored survival. One-half of all the weevils surviving were found in the folds of dead banana leaves on April 15, while the balance were scattered among hay, dried cotton leaves, empty bolls, and in or under earth.

### CAGE EXPERIMENTS OF 1903–4.

During the season of 1903–4 450 weevils were tested in lots of about 50 each. From October 21 to December 16 one or more lots were started each week, part of them being placed outdoors and part indoors. In addition to the confinement of adults, about 400 infested squares were picked from the ground about November 15 and kept until the following March. These squares were examined on March 18. It was found that most of the stages had perished while yet larvæ. Nearly one-fifth of the squares contained dead adults. In the lot among 128 stages there was one adult which was still alive.

Examination in April, 1904, accounted for all but 15 of the 450 weevils confined, but one weevil was found alive, and that one was placed in hibernation on October 29 in a cage out of doors. The results during this season seem to contradict in some respects those obtained during the preceding year, which indicated the favorable nature of inside shelter.

### CAGE EXPERIMENTS OF 1904–5.

The work of the season of 1904–5 was planned to include a number of localities representing in a general way the various portions of the weevil-infested area. In all cases the cages consisted of boxes about 1 by 2 feet in size and covered with 14-mesh galvanized-wire screen-

ing. These were all placed out of doors at various dates between November 3 and December 15, 1904. The examinations were made during April, 1905.

TABLE XII.—*Summary of hibernation experiments, 1904–5.*

| Locality. | Weevils put in hibernation. | Weevils found dead. | Weevils found alive. | Total number of weevils found— | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | In grass, straw, hay, weeds, etc. | On ground. | In ground. | In banana leaves. | In excelsior. | In sorghum stalks. | In canna leaves. | In cornstalks. | In oak leaves. | In bolls cotton stalks. | In paper. | On potato vines. |
| Terrell, Tex | 715 | 244 | 0 | 108 | 68 | 13 | 1 | 3 | 7 | 28 | 6 | .... | .... | .... | .... |
| Paris, Tex | 650 | 254 | 0 | 116 | 58 | 14 | 0 | 8 | 0 | 23 | 8 | 3 | 5 | 19 | .... |
| Keithville, La | 489 | 229 | 0 | 120 | 68 | 10 | 0 | 0 | 0 | 0 | 4 | 24 | 3 | .... | .... |
| Corsicana, Tex | 572 | 278 | 0 | 167 | 60 | 23 | .... | .... | .... | .... | 21 | .... | 5 | 2 | .... |
| Calvert, Tex | 500 | 240 | 0 | 84 | 47 | 45 | .... | 24 | .... | .... | 15 | .... | .... | 11 | 12 |
| Victoria, Tex | 900 | 601 | 11 | 190 | 190 | 6 | 91 | .... | .... | .... | .... | 48 | 12 | .... | .... |
| Total | 3,826 | 1,846 | 11 | 785 | 491 | 111 | 92 | 35 | 7 | 51 | 54 | 75 | 25 | 32 | 12 |

The most striking point shown in this table is the fact that no weevils survived except at Victoria. Even there the percentage was very small. Undoubtedly from 5 to 10 per cent of the weevils placed in the cages must have escaped through the wire before the season became cold enough for all to hibernate. The explanation for the death of all weevils confined north of Victoria, Tex., may be found in the exceptionally severe climatic conditions occurring during this season. These have already been indicated in Table VIII, page 27. It should be stated, however, that while weevils were scarce in the spring of 1905 in all of these localities they were not exterminated in Texas except at Paris. At this place examinations made during the season of 1905 failed to show any weevils in a field which had been quite heavily infested late in the season of 1904.

## HIBERNATION EXPERIMENTS IN SMALL CAGES, 1905–6.

Tests were made at Dallas, Calvert, and Victoria, Tex., representing the northern, central, and southern sections of the infested area. Owing to the increased complexity of the experiments and the more valuable character of the results obtained, it seems advisable to present the data in a somewhat more detailed manner.

TABLE XIII.—*Summary of hibernation experiments in boxes at Dallas, Calvert, and Victoria, Tex., in 1905–6.*

DALLAS.

| When put in. | Kind of rubbish. | Outdoors or indoors. | Weevils put in. | When examined. | Number of weevils found— | | Percentage alive. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Alive. | Dead. | | |
| 1905. | | | | 1906. | | | | |
| Nov. 1 | Corn shucks, grass, cotton leaves. | Out | 100 | Apr. 27 | 0 | 92 | 0 | |
| Do | Cotton leaves | In | 100 | do | 0 | 80 | 0 | In chicken house. |
| Do | do | In | 100 | do | 0 | 64 | 0 | In seed house. |
| Do | Sack of cotton seed | In | 100 | Apr. 28 | 0 | 92 | 0 | Do. |
| Nov. 17 | Grass, leaves, rubbish | Out | 100 | Feb. 19 | 3 | 82 | 3 | |
| Do | do | In | 100 | do | 0 | 87 | 0 | Do. |
| Nov. 18 | Cotton seed | In | 200 | Apr. 30 | 0 | 160 | 0 | Do. |
| Nov. 26 | Only grass | Out | 200 | May 1 | 0 | 165 | 0 | |
| Do | Grass, seed, cotton | In | 200 | do | 0 | 165 | 0 | Do. |
| Dec. 4 | Cotton seed | In | 200 | May 3 | 0 | 181 | 0 | |
| Dec. 11 | Corn shucks, leaves | Out | 200 | do | 0 | 140 | 0 | |
| Do | do | In | 200 | May 1 | 0 | 195 | 0 | |
| Dec. 15 | Cotton seed | In | 900 | May 4 | 0 | 862 | 0 | 300 in each of 3 sacks. |
| | Total | Out | 600 | | 3 | 479 | 0.5 | |
| | | In | 2,100 | | 0 | 1,886 | 0.0 | |

CALVERT.

| When put in. | Kind of rubbish. | Outdoors or indoors. | Weevils put in. | When examined. | Number of weevils found— | | Percentage alive. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Alive. | Dead. | | |
| 1905. | | | | 1906. | | | | |
| Nov. 7 | Corn shucks, grass, cotton. | In | 100 | Apr 18 | 0 | 98 | 0 | |
| Do | do | Out | 94 | do | 1 | 45 | 1 | |
| Nov. 27 | do | In | 205 | do | 0 | 205 | 0 | |
| Do | do | Out | 200 | Apr. 19 | 40 | 145 | 20 | |
| | Total | Out | 294 | | 41 | 190 | 14.0 | |
| | | In | 305 | | 0 | 303 | 0.0 | |

VICTORIA.

| When put in. | Kind of rubbish. | Outdoors or indoors. | Weevils put in. | When examined. | Number of weevils found— | | Percentage alive. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Alive. | Dead. | | |
| 1905. | | | | 1906. | | | | |
| Nov. 5 | Mixed | Out | 100 | Apr. 6 | 2 | 43 | 2 | |
| Nov. 7 | do | Out | 100 | Apr. 7 | 1 | 23 | 1 | |
| Do | do | In | 100 | do | 0 | 73 | 0 | |
| Nov. 13 | do | Out | 100 | Apr. 4 | 4 | 53 | 4 | |
| Do | do | In | 100 | Apr. 5 | 0 | 97 | 0 | |
| Nov. 30 | do | Out | 100 | do | 1 | 39 | 1 | |
| Do | do | In | 100 | do | 0 | 94 | 0 | |
| Dec. 11 | do | Out | 100 | Apr. 7 | 3 | 51 | 3 | |
| Do | do | In | 112 | do | 4 | 100 | 3.57 | |
| | Total | Out | 500 | | 11 | 209 | 2.2 | |
| | | In | 412 | | 4 | 364 | .97 | |
| | Total of 3 localities | Out | 1,394 | | 55 | 878 | 3.9 | |
| | | In | 2,817 | | 4 | 2,553 | .14 | |

In the small-cage experiments of 1905–6 but three localities were tested. In the 26 experiments were placed 4,211 weevils, of which number 1,394 were out of doors and 2,817 indoors. In only one cage did weevils survive within doors, and that was at Victoria, where it would seem that such protection was least needed. The two most striking results were the small survival at Dallas and the remarkably large survival in one of the outdoor experiments at Calvert. In the outdoor tests an average of 3.9 per cent survived,

while in the others but 0.14 per cent survived. In an average of all tests the survival was 1.4 per cent.

The nature of the shelter failed to show any significant influence in these small-cage experiments.

The relative favorableness of outside conditions is shown in the following table by a comparison of the data in each of the three localities. This table does not include the experiments with cotton seed:

TABLE XIV.—*Comparison of survival records outdoors and indoors for three Texas localities in 1905–6.*

| Locality. | Outside. | | | Inside. | | |
|---|---|---|---|---|---|---|
| | Weevils put in hibernation. | Weevils survived. | | Weevils put in hibernation. | Weevils survived. | |
| | | Number. | Percentage. | | Number. | Percentage. |
| Victoria, Tex | 500 | 11 | 2.2 | 412 | 4 | 0.97 |
| Calvert, Tex | 294 | 41 | 14.0 | 305 | 0 | 0 |
| Dallas, Tex | 600 | 3 | .5 | 2,100 | 0 | 0 |
| Total | 1,394 | 55 | 3.9 | 2,817 | 4 | 0.14 |

During this season it is very evident that in all localities outdoor conditions were decidedly more favorable for successful hibernation. Upon the average the survival out of doors was twenty-eight times as successful as in the tests made indoors.

Grouping the experiments according to fifteen-day periods from November 1 to December 15, when they were instituted, the most favorable time for entering hibernation seems to be indicated.

TABLE XV.—*Comparative favorableness of periods for entering hibernation, 1905.*

| Locality. | Period. | | | | | | | | | Total survival. | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nov. 1–15, 1905. | | | Nov. 15–30, 1905. | | | Dec. 1–15, 1905. | | | | |
| | Weevils put in hibernation. | Weevils survived. | | Weevils put in hibernation. | Weevils survived. | | Weevils put in hibernation. | Weevils survived. | | Number. | Per cent. |
| | | Number. | Per cent. | | Number. | Per cent. | | Number. | Per cent. | | |
| Victoria, Tex | 500 | 7 | 1.4 | 200 | 1 | 0.5 | 212 | 7 | 3.3 | 15 | 1.60 |
| Calvert, Tex | 194 | 1 | .5 | 405 | 40 | 10.0 | ..... | ..... | ..... | 41 | 6.80 |
| Dallas, Tex | 300 | 0 | .0 | 600 | 3 | .5 | 400 | 0 | 0 | 3 | .23 |
| Total | 994 | 8 | .8 | 1,205 | 44 | 3.7 | 612 | 7 | 1.1 | 59 | 2.10 |

This table does not include the experiments in cotton seed. The comparisons show that during the fall of 1905, November 15 to 30 was more favorable than either an earlier or later period at Calvert

and Dallas, while at Victoria the period between December 1 and 15 was more favorable.

The shelter conditions within which weevils survived was also determined in these experiments, and the principal points are shown in the following table, which again does not include cotton-seed tests:

TABLE XVI.—*Shelter in which surviving weevils were found in April and May, 1906.*

| Locality. | Bermuda grass and hay. | Excelsior. | Paper. | Banana leaves. | Corn shucks, old cotton stalks, and bolls. | Total. |
|---|---|---|---|---|---|---|
| Victoria, Tex. | 5 | *4 | 1 | 1 | 4 | 15 |
| Calvert, Tex. | | | | | 41 | 41 |
| Dallas, Tex. | 3 | | | | | 3 |
| Total. | 8 | 4 | 1 | 1 | 45 | 59 |

This shows the favorable nature of old corn and cotton stalks, among which the survival in one cage at Calvert was surprisingly large. It also indicates that weevils may survive in varied shelter, and that in all probability the temperature and moisture conditions experienced may be as important as the nature of the shelter in determining survival.

## LARGE-CAGE EXPERIMENTS, KEATCHIE, LA., 1905–6.

With the work of 1905–6 a change was made in the method of carrying on the hibernation experiments. Instead of using numerous small boxes in a number of places, large screen-covered cages were utilized in the fields at Keatchie, La., and Dallas, Tex. The Keatchie cage (Pl. III, fig. 2) was constructed under the direction of Mr. Wilmon Newell, secretary of the State crop pest commission of Louisiana and special field agent, cooperating in the boll weevil investigations. It was probably the largest structure of its kind that has ever been built for an entomological investigation. The interior was divided by partitions into eighteen sections. The shelter conditions for the weevils and the dates upon which weevils were inclosed were planned to represent the extremes of field conditions as to shelter and date of entrance into hibernation. The general plan of the experiment is shown in the first section of Table XVII, and in the last section are included the emergence records for the cage.

Before entering upon a discussion of the work at Keatchie special credit should be given Mr. Wilmon Newell and his assistant, Mr. J. B. Garrett, who were particularly concerned in the execution of the work at Keatchie. Much work has also been done by Mr. W. D. Hunter upon the reports of the Keatchie experiments in arranging the data so as to show the most significant facts.

SEED HOUSE AND HIBERNATION CAGE, KEATCHIE, LA.

Fig. 1.—Seed house opposite which the first sign of weevil work was found at Keatchie, La., in 1905. Fig. 2.—Large cage built for hibernation experiments in 1905–6. (Original.)

TABLE XVII.—*Summary of installation and emergence records in cage at Keatchie, La.*

| Section number. | Where weevils were collected. | When weevils were put in. | Number of weevils put in. | Shelter in cage section. | Emergence records, 1906. March. Number. | March. Per cent. | April. Number. | April. Per cent. | May 1–14. Number. | May 1–14. Per cent. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Louisiana | Nov. 29 | 1,200 | Brush, leaves, moss, stumps, logs; stalks removed. | 2 | 0.166 | 3 | 0.25 | 4 | 0.33 |
| 2 | do | Nov. 25 | 1,000 | Same, but stalks standing | 0 | ..... | 7 | .7 | 10 | 1.0 |
| 3 | do | do | 1,000 | Cotton seed piled; plants left standing. | 1 | .1 | 4 | .4 | 0 | ..... |
| 4 | do | do | 1,000 | Same, but seed left uncovered | 2 | .2 | 5 | .5 | 0 | ..... |
| 5 | do | do | 1,000 | Absolutely bare | 1 | .1 | 1 | .1 | 0 | ..... |
| 6 | Texas | Nov. 23 | 1,000 | Ordinary field | 5 | .5 | 18 | 1.8 | 4 | .4 |
| 7 | do | Nov. 29 | 2,100 | Stalks, grass, etc.: Same as 1 | 2 | .09 | 17 | .81 | 16 | .76 |
| 8 | do | Nov. 25 | 1,500 | Same as 2 | 2 | .14 | 33 | 2.2 | 15 | 1.0 |
| 9 | do | do | 1,000 | Same as 3 | 2 | .2 | 9 | .9 | 3 | .3 |
| 10 | do | do | 1,000 | Same as 4 | 2 | .2 | 15 | 1.5 | 0 | ..... |
| 11 | do | do | 1,000 | Same as 5 | 0 | ..... | 10 | 1.0 | 4 | .4 |
| 12 | do | Nov. 23 | 1,000 | Same as 6 | 0 | ..... | 17 | 1.7 | 12 | 1.2 |
| 13 | Louisiana | Dec. 18 | 1,000 | Stalks left; leaves, etc., added; shaded. | 1 | .1 | 2 | .2 | 1 | .1 |
| 14 | Texas | Dec. 3 | 4,000 | Same as 13, but not shaded | 4 | .1 | 29 | .72 | 17 | .42 |
| 15 | do | do | 4,000 | Same as 14 | 9 | .22 | 94 | 2.35 | 28 | .7 |
| 16 | do | Dec. 8 | 1,000 | do | 1 | .1 | 15 | 1.5 | 5 | .5 |
| 17 | Louisiana | Nov. 28 | 1,000 | do | 4 | .4 | 17 | 1.7 | 10 | 1.0 |
| 18 | do | Nov. 18 | 1,000 | Check on 13; stalks, grass, leaves, not shaded. | 0 | ..... | 15 | 1.5 | 8 | .8 |
| | Totals and averages. | | 25,800 | | 38 | .18 | 311 | 1.2 | 137 | .53 |

| Section number. | Where weevils were collected. | When weevils were put in. | Number of weevils put in. | Shelter in cage section. | Emergence records, 1906. March 1 to May 14. Number. | March 1 to May 14. Per cent. | Total number emerged. | Total per cent of survival. | Rank of section based on per cent of survival. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Louisiana | Nov. 29 | 1,200 | Brush, leaves, moss, stumps, logs; stalks removed. | 9 | 0.75 | 26 | 2.16 | 11 |
| 2 | do | Nov. 25 | 1,000 | Same, but stalks standing | 17 | 1.7 | 25 | 2.5 | 9 |
| 3 | do | do | 1,000 | Cotton seed piled; plants left standing. | 5 | .5 | 6 | .6 | 16 |
| 4 | do | do | 1,000 | Same, but seed left uncovered | 7 | .7 | 8 | .8 | 15 |
| 5 | do | do | 1,000 | Absolutely bare | 2 | .2 | 4 | .4 | 17 |
| 6 | Texas | Nov. 23 | 1,000 | Ordinary field | 27 | 2.7 | 38 | 3.8 | 6 |
| 7 | do | Nov. 29 | 2,100 | Stalks, grass, etc.: Same as 1 | 35 | .66 | 44 | 2.09 | 13 |
| 8 | do | Nov. 25 | 1,500 | Same as 2 | 50 | 3.33 | 64 | 4.26 | 3 |
| 9 | do | do | 1,000 | Same as 3 | 14 | 1.4 | 17 | 1.7 | 14 |
| 10 | do | do | 1,000 | Same as 4 | 17 | 1.7 | 22 | 2.2 | 10 |
| 11 | do | do | 1,000 | Same as 5 | 14 | 1.4 | 26 | 2.6 | 8 |
| 12 | do | Nov. 23 | 1,000 | Same as 6 | 29 | 2.9 | 55 | 5.5 | 1 |
| 13 | Louisiana | Dec. 18 | 1,000 | Stalks left; leaves, etc., added; shaded. | 4 | .4 | 8 | .8 | 15 |
| 14 | Texas | Dec. 3 | 4,000 | Same as 13, but not shaded | 50 | 1.25 | 86 | 2.15 | 12 |
| 15 | do | do | 4,000 | Same as 14 | 132 | 3.3 | 170 | 4.25 | 4 |
| 16 | do | Dec. 8 | 1,000 | do | 21 | 2.1 | 35 | 3.5 | 7 |
| 17 | Louisiana | Nov. 28 | 1,000 | do | 31 | 3.1 | 41 | 4.1 | 5 |
| 18 | do | Nov. 18 | 1,000 | Check on 13; stalks, grass, leaves, not shaded. | 23 | 2.3 | 53 | 5.3 | 2 |
| | Totals and averages. | | 25,800 | | 487 | 1.5 | 728 | 2.82 | ..... |

The beginning of this work occurred so late in November that none of the sections can be considered as having been placed in hibernation early. Cold weather occurred between about November 30 and December 3, during which time the majority of weevils entered hibernation. Emergence appears to have begun on March 22, and the last weevils emerged on June 28. The emergence during April and May was quite uniform, while during June it decreased rather steadily. In these records no allowance has been made for the escape of weevils through the wire on the cage. Using the number placed in the cage (25,800) as a basis, the 728 weevils which emerged constitute a survival of 2.82 per cent. It is impossible to call attention to all of the many interesting points shown in this table. Special emphasis, however, will be given several points through the rearrangement of the significant data in succeeding tables.

Since climatic conditions are primarily responsible for hibernation and the emergence of weevils therefrom, the records should be studied in relation to a chart of the temperature conditions, such as is given in figure 1. No climatic records are available for Keatchie previous to the beginning of these observations upon March 15. The emergence of weevils may well be shown in relation to the range in temperature upon the same chart. In studying the effects of temperature variations upon weevil activity it has been found that those temperatures which are about 43° F. alone produce activity among the weevils. Because of this fact 43° F. is regarded as the starting point in emergence records, and all temperatures above 43 degrees may be spoken of as "effective temperatures" upon the following diagram; the average between the maximum and minimum extremes for the day is recorded as the mean average temperature. While it is probably true that maximum temperatures have a special significance in their effect upon emergence from hibernation, and that minimum temperatures have a special effect upon entrance into hibernation, it will be more simple and sufficient in this study to use the single line representing mean average temperature during the emergence period.

From this diagram it will be seen that the emergence at Keatchie in 1906 occurred practically during four rather clearly defined periods. These periods are separated by marked declines in the mean average temperature. It will be noticed that as it became warmer following these cold periods there was an increased emergence of the weevils. After the middle of May so large a proportion of the living weevils had emerged that the number recorded became gradually smaller, although the temperature rose still higher.

Some of the special facts demanding attention are those relating to the effect of the various conditions of shelter upon the survival of weevils, the relation of emergence to effective temperature in

various periods, the relation of the time of putting into hibernation to the time of emergence therefrom, the relation of accumulated effect-

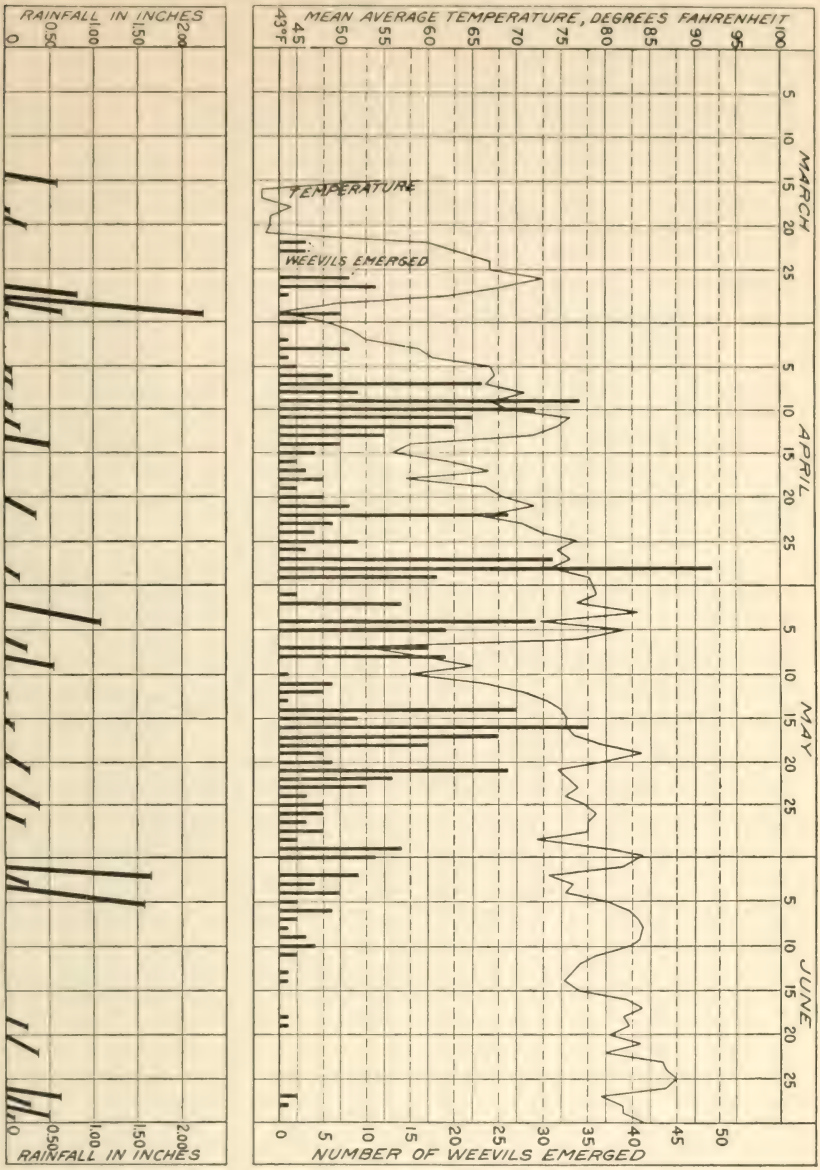



FIG. 1.—Chart showing mean average temperature, rainfall, and weevil emergence, Keatchie, La., March to June, 1906.

ive temperatures to emergence, and the longevity of the emerged weevils. These subjects will be considered under succeeding topics.

## FAVORABLE CONDITIONS FOR HIBERNATION.

For a study of favorable conditions for hibernation those sections have been selected which are most strictly comparable in respect to

the time weevils were placed therein, the source of the weevils, and the nature of the shelter. Practically one-half of the weevils used were collected in Texas and sent to Keatchie for this work. The sections used in this comparison received weevils between November 23 and 29.

TABLE XVIII.—*Favorable conditions for hibernation determined by rank in percentage of weevils surviving at Keatchie, La., in 1905–6.*

| Section number in cage. | Nature of shelter. | Weevils put in. | Weevils survived. | | Rank of section. |
|---|---|---|---|---|---|
| | | | Number. | Per cent. | |
| 6 and 12 | Ordinary field stalks, grass, etc | 2,000 | 93 | 4.65 | 1 |
| 2 and 8 | Brush, leaves, stumps, logs; stalks standing | 2,500 | 99 | 3.56 | 2 |
| 1 and 7 | Same as above, but stalks removed | 3,300 | 70 | 2.12 | 3 |
| 4 and 10 | Cotton seed, piled but uncovered; stalks standing | 2,000 | 30 | 1.50 | 4 |
| 5 and 11 | Absolutely bare ground | 2,000 | 30 | 1.50 | 4 |
| 3 and 9 | Cotton seed piled and covered; stalks left standing | 2,000 | 23 | 1.15 | 5 |

It is evident that ordinary field conditions where stalks are allowed to stand together with the grass and leaves littered over the ground are as favorable for successful hibernation as any conditions. It must be admitted that the shelter conditions in the bare sections (5 and 11) are not such as would occur in a field plowed in the fall because of the fact that the inclosed weevils could still find shelter in the structure of the cage itself. This will undoubtedly explain the survival of 1.5 per cent in two sections having no rubbish on the ground. It is apparent, however, that even with this advantage of cage structure over bare ground, slightly more than three times this percentage of weevils survived where ordinary field conditions existed. Without the shelter afforded by the cage this difference would undoubtedly be very much greater. In 9 sections which contained rubbish, among 15,500 weevils, 567, or 3.66 per cent, survived. The shelter may therefore be held accountable for increasing the survival at least 2.1 per cent. Thus upon an area where no more than 15 weevils might survive without protection, 36 at least might be expected to survive with the protection.

### EFFECT OF ACCLIMATIZATION UPON SURVIVAL AND EMERGENCE.

It has already been mentioned that about one-half of the weevils used in this work were collected in Texas and one-half at Keatchie, La. In order to determine whether this difference in the geographical section in which the weevils developed might exert an influence upon their survival and emergence the records for a number of comparable sections are combined. These weevils were all placed in hibernation between November 25 and 29, 1905.

TABLE XIX.—*Comparison of emergence records at Keatchie, La., for weevils collected in Louisiana with those collected in Texas.*

| Date. | Percentage of emergence during each month based upon total emergence of— | |
|---|---|---|
| | 6,200 weevils collected in Louisiana. | 6,600 weevils collected in Texas. |
| 1906. | | |
| March | 9.09 | 4.6 |
| April | 33.63 | 48.6 |
| May 1–14 | 21.82 \ 50 | 21.9 \ 42.2 |
| May 15–June 1 | 28.18 / | 20.3 / |
| June 2–30 | 7.28 | 4.6 |
| | 100.00 | 100.0 |

Altogether in these sections 110 of the Louisiana weevils and 173 of the Texas weevils emerged, making a percentage of total survival in the former case of 1.77 and in the latter case of 2.62. On the whole the Texas weevils emerged slightly earlier than did those collected in Louisiana, but the records are too nearly similar to indicate that such would regularly be the case.

### RELATION OF EMERGENCE TO EFFECTIVE TEMPERATURES.

The practical point in these studies of temperature and emergence relationships is to ascertain the facts upon which emergence depends, so that it may be possible from a study of temperature records for any locality to form fairly reliable conclusions as to the effects which those temperature conditions may have had upon weevil activity. In this way it may be possible to determine approximately the time when weevil emergence begins, the time when the majority of weevils will probably have left their hibernation quarters, and approximately the time at which emergence becomes complete. In this connection it will be profitable to compare the records for Dallas, Tex., with those for Keatchie, La., for the same periods.

The total effective temperature is obtained by computing the sum of the mean average effective temperatures for each of the days included within the period shown. For example, if the mean average temperature for the first day of a period is 60° and for the second day 68°, the average effective temperature for the two days is 17° and 25°, respectively. The sum of these, or 42°, is the total effective temperature for those two dates.

TABLE XX.—*Relation of effective temperatures to emergence at Keatchie, La., and Dallas, Tex., 1906.*

| Periods of emergence. | Total effective temperature. | | Average effective temperature. | | Number of weevils emerging. | |
|---|---|---|---|---|---|---|
| | Keatchie. | Dallas. | Keatchie. | Dallas. | Keatchie. | Dallas. |
| | °F. | °F. | °F. | °F. | | |
| Mar. 15–21 | 12.0 | 5.5 | 1.7 | 0.78 | 0 | 0 |
| Mar. 22–27 | 141.0 | 151.8 | 23.5 | 25.3 | 25 | 2 |
| Mar. 28–Apr. 2 | 37.0 | 66.6 | 7.4 | 11.1 | 12 | 0 |
| Apr. 3–13 | 275.5 | 243.6 | 25.0 | 22.14 | 165 | 28 |
| Apr. 14–20 | 118.5 | 124.1 | 16.9 | 17.7 | 28 | 0 |
| Apr. 21–May 5 | 484.7 | 435.8 | 32.3 | 29.0 | 187 | 18 |
| May 6–13 | 176.0 | 159.8 | 22.0 | 19.9 | 49 | 0 |
| May 14–23 | 339.0 | 300.2 | 33.9 | 30.0 | 173 | 7 |
| May 24–29 | 201.0 | 196.8 | 33.5 | 32.8 | 23 | 0 |
| May 30–June 11 | 413.0 | 478.0 | 37.5 | ..... | 65 | ..... |
| June 12–30 | 667.0 | 700.0 | 39.2 | ..... | 7 | ..... |

An examination of this table shows three very distinct periods of emergence, the first being from April 3 to 13, inclusive; the second from April 21 to May 5, inclusive; and the third from May 14 to 23. No weevils emerged from the Dallas cages after May 23. At Keatchie a fourth period may be considered as occurring between May 30 and June 11. In this place the emergence ceased on June 28. It is noticeable that between June 20 and 27 no weevils had emerged. It will be noticed in the table that the periods of largest emergence are separated by periods having decidedly lower temperatures, during which emergence was decreased, although it did not cease entirely.

The relation of emergence to 5-degree increments in effective temperature is shown in Table XXI.

TABLE XXI.—*The relation of emergence to increase in effective temperature at Keatchie, La., and Dallas, Tex., 1906.*

| Range of effective temperatures. | Keatchie, La. | | Dallas, Tex. | | Total number of weevils emerged. | Per cent, based on grand total emerged. |
|---|---|---|---|---|---|---|
| | Number of weevils emerging. | Per cent of total emergence. | Number of weevils emerging. | Per cent of total emergence. | | |
| 1–14° | 20 | 2.7 | 0 | 0 | 20 | 2.5 |
| 15–20° | 52 | 7.1 | 2 | 3.6 | 54 | 6.8 |
| 21–25° | 116 | 16.0 | 25 | 45.5 | 141 | 17.8 |
| 26–30° | 127 | 17.5 | 18 | 32.7 | 145 | 18.5 |
| 31–35° | 309 | 42.4 | 10 | 18.2 | 319 | 40.7 |
| 36–40° | 84 | 11.5 | 0 | 0 | 84 | 10.7 |
| 41–50° | 20 | 2.7 | 0 | 0 | 20 | 2.5 |
| Total. | 728 | 100.0 | 55 | 100.0 | 783 | 100.0 |

The number of weevils emerging under 14 degrees of effective temperature, or 57° F., is very small indeed. From that point the emergence increases with the increase in temperature until after a majority of the weevils have emerged. Most weevils left their winter quarters during an effective temperature averaging between

21 and 35 degrees. At Keatchie 75 per cent and at Dallas 96 per cent of the total emergence took place between these limits. At Dallas the largest emergence occurred between 21 and 25 degrees of effective temperature, while at Keatchie the largest emergence occurred between 31 and 35 degrees.

In considering the effect of temperature upon emergence it must be remembered that the nature of the shelter within which the weevil hibernates must inevitably have an important bearing on the time at which the weevil becomes active.

## RELATION OF TIME OF ENTRANCE INTO HIBERNATION TO SURVIVAL AND EMERGENCE.

It has previously been stated that none of these experiments was instituted more than about a week before it became cold enough for practically all weevils to hibernate. For this comparison it is possible to use only the data for those sections having similar conditions as to (1) the source from which weevils were obtained, (2) the time when they were placed in the cage, and (3) the general nature of the shelter afforded.

TABLE XXII.—*Relation of time of emergence in 1906 to time of starting hibernation in 1905.*

| Section number in cage. | When weevils were put in. | Percentage of total emergence, 1906, occurring in— | | | | | Per cent of survival. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | | March. | April. | May 1–14. | May 15–June 1. | June 2–30. | | |
| 7 and 8..... | Nov. 25 and 29. | 3.7 | 46.3 | 28.7 | 15.7 | 5.5 | 3.0 | Texas weevils. |
| 14, 15, and 16. | Dec. 3 and 8. | 4.8 | 47.4 | 17.1 | 24.7 | 5.5 | 3.23 | |
| 17..... | Nov. 28... | 9.7 | 41.4 | 24.4 | 22.0 | 2.4 | 4.1 | Louisiana weevils. |
| 18..... | Nov. 18... | 0 | 28.3 | 15.0 | 32.0 | 24.5 | 5.3 | |

In the first section of the table, among weevils collected in Texas, it is apparent that there was practically no difference in the time of emergence between those placed in hibernation from November 25 to 29 and those started December 3 to 8. In the second part of the table, among the Louisiana weevils, those entering hibernation November 18 emerged more slowly than did those placed in the cage November 28. The explanation of this may probably be found in the fact that the first date was not sufficiently early to insure the death of many weevils by starvation before they could hibernate. It did, however, allow a larger proportion of them to penetrate deeply into the shelter than in the case of weevils placed in the cage ten days later, which was only one day before a marked decrease in temperature. The weevils placed in the cage on December 3 and 8 experienced warmer temperatures than those placed in on the 28th of November, and, therefore, found conditions more favorable for their

entrance into hibernation. The records indicate that there is a most favorable time for entrance during which weevils may find shelter from which they will emerge rather later than the average during the following spring.

## THE RELATIONSHIP OF ACCUMULATED EFFECTIVE TEMPERATURE TO EMERGENCE.

In studying the relationship of accumulated effective temperature to emergence the initial point has been set arbitrarily at February 1. It would be both interesting and profitable if we could determine positively the exact effective temperature conditions under which emergence from hibernation begins. This point will be further discussed in the light of the additional records obtained in Texas in 1907.

The object in this particular study is to determine the relation of accumulated effective temperature to the accumulation in emergence. The records for both Keatchie and Dallas are included for the sake of comparison.

TABLE XXIII.—*Relation of accumulated effective temperature to the beginning and accumulation of emergence, Keatchie, La., and Dallas, Tex.*

| Periods of emergence. | Accumulated effective temperature. | | Accumulated number of weevils emerged. | | Accumulated percentage of total emergence. | |
|---|---|---|---|---|---|---|
| | Keatchie. | Dallas. | Keatchie. | Dallas. | Keatchie. | Dallas. |
| 1906. | °F. | °F. | | | | |
| Feb. 28 | 145.6 | 208.6 | 0 | 0 | 0 | 0 |
| Mar. 1–14 | 282.1 | 325.0 | 0 | 0 | 0 | 0 |
| Mar. 15–21 | 294.1 | 330.5 | 0 | 0 | 0 | 0 |
| Mar. 22–27 | 435.1 | 482.3 | 25 | 2 | 3.4 | 3.6 |
| Mar. 28–Apr. 2 | 472.1 | 548.9 | 37 | 2 | 5.0 | 3.6 |
| Apr. 3–13 | 747.6 | 792.5 | 202 | 30 | 27.5 | 54.5 |
| Apr. 14–20 | 866.1 | 916.6 | 230 | 30 | 31.3 | 54.5 |
| Apr. 21–May 5 | 1,350.8 | 1,362.4 | 417 | 48 | 56.8 | 87.2 |
| May 6–13 | 1,526.8 | 1,512.2 | 466 | 48 | 63.4 | 87.2 |
| May 14–23 | 1,865.8 | 1,812.4 | 639 | 55 | 87.0 | 100.0 |
| May 24–29 | 2,066.8 | 2,009.2 | 662 | 55 | 90.0 | ..... |
| May 30–June 11 | 2,479.8 | 2,487.6 | 727 | 55 | 99.0 | ..... |
| June 12–30 | 3,146.8 | 3,188.0 | 734 | 55 | 100.0 | ..... |

Emergence at Dallas became complete with the accumulation of slightly over 1,800 degrees of effective temperature, while at Keatchie complete emergence required slightly over 3,000 degrees of effective temperature. At Dallas 87 per cent of weevils had emerged when 1,512 degrees of effective temperature had accumulated and the same percentage had emerged at Keatchie with 1,865 degrees effective temperature. For the last 13 per cent of weevils emerging but 300 degrees of temperature accumulated at Dallas, while at Keatchie nearly 1,300 degrees accumulated. It is probable that at Dallas during this season the emergence in the cage was completed somewhat sooner than would have been the case normally, on account of the late period of starting the experiments.

At Victoria in the spring of 1904 the period of emergence from hibernation was determined in the field under exceptionally favorable conditions. A severe drought, occurring immediately after most of the cotton had been planted, so retarded germination that the sprout cotton developed nearly two months in advance of the planted. Large numbers of weevils emerged before most of the planted cotton was through the ground. Practically the only food supply afforded these weevils was found in the sprout cotton. By reducing the number of sprout plants upon a field of 65 acres it was possible to examine at frequent intervals all of the plants. Since all weevils found at each examination were collected and removed from the field those found at the next subsequent examination may be considered as having emerged in the interval. The development of squares upon the most advanced plants was not sufficient to make it possible for any weevils of the first generation to have become adults before June 1. The collections from the sprout plants were continued until May 26, and it is probable that some weevils emerged from hibernation after this date. Our knowledge of the weevils at that time was not such as to enable us to distinguish accurately between hibernated and recently emerged adults after that date. For that reason May 26 was considered as representing the conclusion of emergence from hibernation, although it probably continued longer.

TABLE XXIV.—*Relation of accumulated effective temperature to accumulated emergence in field observations at Victoria, Tex., in 1904.*

| Periods. | Accumulated effective temperature. | Accumulated number of plants of cotton sprouts examined. | Accumulated percentage of plants examined to entire number examined. | Accumulated number of weevils found. | Accumulated percentage of weevils at each date to entire number found. |
|---|---|---|---|---|---|
| | °F. | | | | |
| Feb. 1–28 | 508.0 | None. | None. | None. | None |
| Mar. 1–18 | 585.5 | 250 | 4.2 | 19 | 2.93 |
| Mar. 19–25 | 1,117.5 | 650 | 11.0 | 39 | 6.01 |
| Mar. 26–31 | 1,240.0 | 1,190 | 20.1 | 65 | 10.03 |
| Apr. 1–5 | 1,378.5 | 1,720 | 29.1 | 100 | 15.46 |
| Apr. 6–12 | 1,537.0 | 2,120 | 35.9 | 160 | 24.60 |
| Apr. 13–16 | 1,656.0 | 2,320 | 39.3 | 200 | 30.80 |
| Apr. 17–May 1 | 2,104.0 | 2,570 | 43.5 | 224 | 34.56 |
| May 2–11 | 2,374.0 | 2,990 | 50.6 | 376 | 58.00 |
| May 12–19 | 2,584.0 | 4,163 | 70.5 | 521 | 81.00 |
| May 20–26 | 2,814.5 | 5,900 | 100.0 | 648 | 100.00 |

A comparison of Tables XXIII and XXIV shows that there was a much greater accumulation of temperature at Victoria for the same percentage of emergence than occurred at either Dallas or Keatchie, although the Keatchie record appears to exceed the Victoria record in the amount of accumulated temperature accompanying complete emergence. It seems very probable that in the field records the accumulations are excessive because of two facts; first, at each

examination all weevils were considered as emerging upon the date of the examination, whereas in the cages the weevils were collected daily. The second reason is that upon plants in the field there was a much greater possibility of overlooking weevils which were present and which might be found and counted as having emerged upon some succeeding examinations. Table XXIV is, however, of value in supporting the records given in Table XXIII, especially because similarly favorable conditions for determining the full period of emergence in the field may rarely occur.

### LONGEVITY OF WEEVILS AFTER EMERGENCE IN KEATCHIE EXPERIMENTS.

For determining longevity after emergence the weevils emerging during short periods were placed together in a smaller cage provided with a variety of rubbish but with no food. Examinations of the small cages were made at frequent intervals and the period between the average date when weevils were placed in the cage and the average date of examinations was recorded. The figures are arranged chronologically according to emergence.

TABLE XXV.—*Longevity of weevils after emergence from hibernation, without food, at Keatchie, La., 1906.*

| Date of emergence. | Number of weevils emerged. | Weevil-days.[a] | Average number of days lived. | Date of emergence. | Number of weevils emerged. | Weevil-days.[a] | Average number of days lived. |
|---|---|---|---|---|---|---|---|
| 1906. | | | | 1906. | | | |
| March 26 | 1 | 62.0 | 62.0 | May 7 | 16 | 292.5 | 18.2 |
| April 10 | 44 | 905.5 | 21.7 | May 8 | 16 | 262.0 | 16.3 |
| April 11 | 35 | 751.0 | 21.4 | May 10 | 1 | 1.0 | 1.0 |
| April 12 | 29 | 678.5 | 23.4 | May 11 | 6 | 54.5 | 9.0 |
| April 13 | 8 | 261.0 | 32.6 | May 12 | 5 | 13.0 | 3.2 |
| April 14 | 7 | 169.0 | 24.1 | May 13 | 1 | 1.5 | 1.5 |
| April 15 | 5 | 100.5 | 20.1 | May 14 | 8 | 58.5 | 7.3 |
| April 16 | 2 | 59.0 | 29.5 | May 15 | 2 | 26.0 | 13.0 |
| April 17 | | | | May 16 | 13 | 169.5 | 13.0 |
| April 19 | 2 | 55.0 | 27.5 | May 17 | 6 | 58.0 | 9.6 |
| April 20 | 11 | 119.0 | 10.8 | May 18 | 4 | 48.5 | 12.1 |
| April 21 | 9 | 92.0 | 10.2 | May 22 | 2 | 23.5 | 11.7 |
| April 22 | 23 | 378.5 | 16.4 | May 23 | 2 | 29.0 | 14.5 |
| April 23 | 6 | 132.5 | 22.0 | May 25 | 2 | 26.5 | 13.2 |
| April 24 | 4 | 36.0 | 9.0 | May 28 | 1 | 1.5 | 1.5 |
| April 25 | 9 | 83.5 | 9.2 | May 29 | 1 | 7.5 | 7.5 |
| April 26 | 3 | 24.0 | 8.0 | May 30 | 4 | 35.0 | 8.7 |
| April 28 | 46 | 855.0 | 18.5 | June 9 | 1 | 7.0 | 7.0 |
| April 30 | 18 | 313.0 | 17.3 | June 19 | 1 | 4.0 | 4.0 |
| May 1 | 2 | 15.0 | 7.5 | | | | |
| May 2 | 15 | 173.0 | 11.5 | Totals and average | 418 | 7,155.0 | 17.11 |
| May 4 | 28 | 431.0 | 15.3 | | | | |
| May 5 | 19 | 342.0 | 18.0 | | | | |

[a] In the third column of the table the expression "weevil-days" is used to signify the total number of days lived by the total number of weevils recorded for a certain date. For example, if one weevil had lived 10 days, a second 15 days, and a third 23 days the total number of weevil-days for these 3 individuals would be 48 and the average number of days lived would be 16.

It is noticeable that weevils emerging early in the season survived far longer than the average period, while those emerging toward the end of the season survived for less than the average period. For the 418 weevils tested the average duration of life without food proved to be slightly over seventeen days.

## LARGE-CAGE EXPERIMENTS AT DALLAS, TEX., 1905–6.

The work at Dallas for 1905–6 was planned especially to check the results of the experiments at Keatchie which have been described. The cage used (Pl. IV, fig. 1) was divided into four sections, each having a ground area of 100 square feet. In one section the natural conditions of shelter were left unchanged (Pl. IV, fig. 2). There was practically no grass upon the ground, but the growth of stalks was quite heavy. In the other three sections the shelter provided (Pl. V, figs. 1 and 2) for the weevils was arranged in such a way that it might be possible to divide each section into two parts by a middle partition. Unfortunately the first cold weather occurred before the weevils could be placed in these sections, and it was necessary to keep the weevils confined in boxes for several days until it became sufficiently warm to render them active so that they might find shelter in the cages. The weevils were liberated at approximately the center of each section and allowed to move in any direction they might choose. The object of this was to determine whether particularly favorable rubbish might exert a special attraction for the weevils.

About three weeks after the weevils were liberated an examination was made of each section and the number of weevils crawling actively upon the wire was determined. An examination of the boxes from which the weevils were liberated and which had been left undisturbed in the cages during this period showed that a large mortality had occurred before the weevils really entered hibernation. Table XXVI shows the principal points in regard to the beginning of the experiments and the emergence of the weevils during the following spring.

TABLE XXVI.—*Large-cage experiments in hibernation at Dallas, Tex., 1905–6.*

| Section of cage. | Kind of shelter. | Weevils put in. | Active weevils, December 26, 1905. | Weevils found dead, December 26, 1905. | Percentage of weevils active, December, 1905. | Percentage of living among those examined. | Date of first emergence, 1906. | Day of largest emergence, 1906. |
|---|---|---|---|---|---|---|---|---|
| I | Cotton stalks | 2,600 | 375 | 615 | 14.4 | 38.0 | Apr. 4 | May 2 |
| II: | | | | | | | | |
| Pt. 1 | Cotton stalks removed March 22, 1906. | 2,500 | 200 | 515 | 8.0 | 28.0 | Mar. 22 | Apr. 9 |
| Pt. 2 | Cotton stalks and leaves. | | | | | | Apr. 4 | Apr. 11 |
| III: | | | | | | | | |
| Pt. 1 | Bare | 2,500 | 260 | 1,205 | 10.4 | 17.7 | Apr. 23 | Apr. 23 |
| Pt. 2 | Hay | | | | | | May 14 | May 14 |
| IV: | | | | | | | | |
| Pt. 1 | Piled boxes | 2,500 | 238 | 1,625 | 9.5 | 12.7 | Apr. 4 | Apr. 11 |
| Pt. 2 | Corn and cotton stalks. | | | | | | Apr. 9 | Apr. 9 |
| | Total and average. | 10,100 | 1,073 | 3,960 | 10.6 | 21⅓ | | |

TABLE XXVI.—*Large-cage experiments in hibernation at Dallas, Tex., 1905–6*—Con.

| Section of cage. | Kind of shelter. | Emergence by periods. | | | | | | | Total survival. | Percentage of survival. | Rank of cages on basis of survival. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mar. 22–31. | Apr. 1–10. | Apr. 11–20. | Apr. 21–30. | May 1–10. | May 11–20. | May 21–31. | | | |
| I | Cotton stalks | 0 | 1 | 2 | 4 | 4 | 2 | 0 | 13 | 0.5 | 2 |
| II: | | | | | | | | | | | |
| Pt. 1 | Cotton stalks removed March 22, 1906. | 2 | 3 | 0 | 3 | 0 | 0 | 0 | 8 | 1.04 | 4 |
| Pt. 2 | Cotton stalks and leaves | 0 | 6 | 7 | 3 | 1 | 1 | 0 | 18 | ..... | 1 |
| III: | | | | | | | | | | | |
| Pt. 1 | Bare | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 2 | .12 | 5 |
| Pt. 2 | Hay | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | ..... | 7 |
| IV: | | | | | | | | | | | |
| Pt. 1 | Piled boxes | 0 | 4 | 3 | 2 | 0 | 1 | 2 | 12 | .56 | 3 |
| Pt. 2 | Corn and cotton stalks | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | ..... | 6 |
| | Total and average | 2 | 17 | 12 | 13 | 5 | 5 | 2 | 56 | .5 | |

The division of sections 2, 3, and 4 was made by inserting a partition of cheese cloth early in the spring of 1906 before any weevils became active. The percentage of survival has been based upon the total number of weevils placed in the four sections. It should be borne in mind that the conditions at the time of entrance into hibernation were decidedly unfavorable for the weevils, as is shown in the fact that about 35 per cent had died before December 26 and under such conditions as to indicate that they were very weak at the time they were placed in the cage. No allowance has been made for the escape of weevils through the wire. It thus appears that approximately 1 per cent of the weevils which really may be said to have entered hibernation survived and emerged between March 21 and May 31. The survival in the bare section was less than one-fourth of the smallest survival in the sections provided with rubbish. For the sake of comparison with the records at Keatchie, La., some data from the Dallas experiments have been used in connection with those at Keatchie in several of the tables which have already been given.

## NATURE OF WEEVIL ACTIVITY FOLLOWING EMERGENCE FROM HIBERNATION.

In following the activity of emerged weevils it was deemed advisable to pursue a very different method at Dallas from that which has been described at Keatchie. Instead of removing weevils from the sections in which they had emerged, each weevil was marked in such a way as to make it possible to recognize it individually and the weevils were allowed to remain practically undisturbed in the section where they had spent the winter. In making the daily examinations record was kept of the appearance or disappearance of each individual weevil. No food was supplied in any of the sections until

HIBERNATION EXPERIMENTS, DALLAS, TEX., 1905-6.

Fig. 1.—Four-section cage used for experiments, built over cotton. Fig. 2.—Shelter conditions as occurring naturally in section 1. (Original.)

SHELTER CONDITIONS IN DALLAS, TEX., EXPERIMENTS, 1905-6.

Fig. 1.—Piled cotton stalks and piled boxes in section 2. Fig. 2.—Standing cotton stalks versus piled leaves, section 3. (Original.)

toward the close of the experiments in May, when seed was planted and cotton began growing before the last weevils emerged. Some very interesting results were obtained from this method of observation. A majority of the weevils were seen a second time, and some disappeared and reappeared as many as eight times. The longest period between the first and second appearances of any individual was forty-three days.

TABLE XXVII.—*Intermittent activity of unfed weevils after emergence, at Dallas, Tex., 1906.*

| Number of weevils seen— | | | | | | | | Weevils "rehibernated"— | | | | | | Average survival, number of days. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Once. | | Twice. | | Three times. | | |
| Once. | Twice. | Three times. | Four times. | Five times. | Six times. | Seven times. | Eight times. | Number. | Days. | Number. | Days. | Number. | Days. | |
| 46 | 26 | 15 | 11 | 6 | 2 | 2 | 1 | 17 | 8.7 | 6 | 7.2 | 2 | 3.5 | 6.8 |

As has been previously shown, entrance into hibernation is a gradual process and weevils which have first become quiet may subsequently become active and seek other shelter before finally hibernating. In a very similar way emergence from hibernation is gradual but extended throughout a longer period of time than is entrance into hibernation. The observations recorded in Table XXVII also show conclusively that weevils may leave their winter quarters during warm days and, failing to find food, they may again become quiet and emerge again after a considerable interval. This fact has an important bearing upon the proposition which is frequently advanced by planters of starving the weevils in the spring by deferring the time of planting. While many weevils might perish in this way, it is certain that many more would be able to survive and reappear at intervals, so that there would be plenty of weevils to infest the crop, even though this might be planted as late as is possible to secure any yield.

Other observations were made upon the intermittent activity of unfed weevils during the spring of 1906. Weevils from Calvert, Victoria, and Brenham, Tex., were tested. The weevils from Calvert and Victoria, Tex., had been confined in hibernation cages throughout the winter. Those from Brenham were collected in the field early in March. None of these weevils had tasted food after emergence. In these tables the date of death, unless otherwise indicated, is considered as having been the middle date between the last examination at which a weevil was found alive and that at which it was found dead.

TABLE XXVIII.—*Intermittent activity of unfed emerged weevils, 1906.*

| Locality. | When collected. | When put in hibernation. | When removed from hibernation. | When rehibernated. | Weevils put in rehibernation. | Date of first examination. |
|---|---|---|---|---|---|---|
| | 1905 | 1905 | 1906 | 1906 | | |
| Calvert, Tex. | Nov. 25 | Nov. 27 | Apr. 19 | Apr. 23 | 20 | May 10 |
| Victoria, Tex. | Nov. 7, 13<br>Dec. 11 | Nov. 7, 13<br>Dec. 11 | Apr. 6 | Apr. 16 | 7 | Apr. 24 |
| | 1906 | | | | | |
| Brenham, Tex. | Nov. 1 | ..... | Mar. 1 | Mar. 7 | 8 | May 11 |

| Locality. | Weevils surviving. | Date of second examination. | Weevils surviving. | Date of third examination. | Weevils surviving. | Date of death of longest survival. | Average length of life in rehibernation. |
|---|---|---|---|---|---|---|---|
| | | | | | | | *Days.* |
| Calvert, Tex. | 10 | May 22 | 6 | June 8 | 0 | June 8 | 30.4 |
| Victoria, Tex. | 3 | May 10 | 0 | ..... | ..... | May 10 | 19.1 |
| Brenham, Tex. | 2 | May 23 | 1 | May 31 | 0 | May 31 | 67.4 |

The records for Calvert and Brenham show a very remarkable power of endurance in some weevils, the average survival for the two lots of 20 and 8 weevils being over thirty and sixty days, respectively.

## CLIMATIC CONDITIONS PRODUCING EMERGENCE FROM HIBERNATION AT DALLAS, TEX., IN 1906.

In the figure given below, representing climatic conditions and the emergence at various dates, the temperature line given represents only the mean average effective temperature.

In this case, as at Keatchie, the emergence occurred especially during four well-defined periods and the conclusions stated in connection with figure 1 apply equally well to the results shown in figure 2.

## EMERGENCE IN THE FIELD AT VICTORIA, TEX., IN 1906.

The observations upon emergence in the field at Victoria, Tex., in 1906, were begun too late in the spring to indicate the limits of the first part of the period of emergence. For this work a field of about one-half acre was selected in which it was apparent early in May that there would be a large number of hibernated adults. The observations were planned to furnish information particularly upon two points under field conditions: (1) The determination of the period of emergence and (2) the period of activity of emerged weevils. The work was done by Mr. A. C. Morgan, who devoted particular attention to a study of this field throughout the season of 1906. The method followed was to examine every plant and every square or boll throughout this area. After the first two examina-

tions had been made it became apparent that some method must be adopted to enable the weevils found at each examination to be distinguished. At each subsequent examination, therefore, the weevils found were marked with a paint of a different color. Early in the season the weevils emerging from hibernation were sufficiently numerous to practically prevent the setting of fruit upon this area. The first weevils of a new generation did not begin to appear until

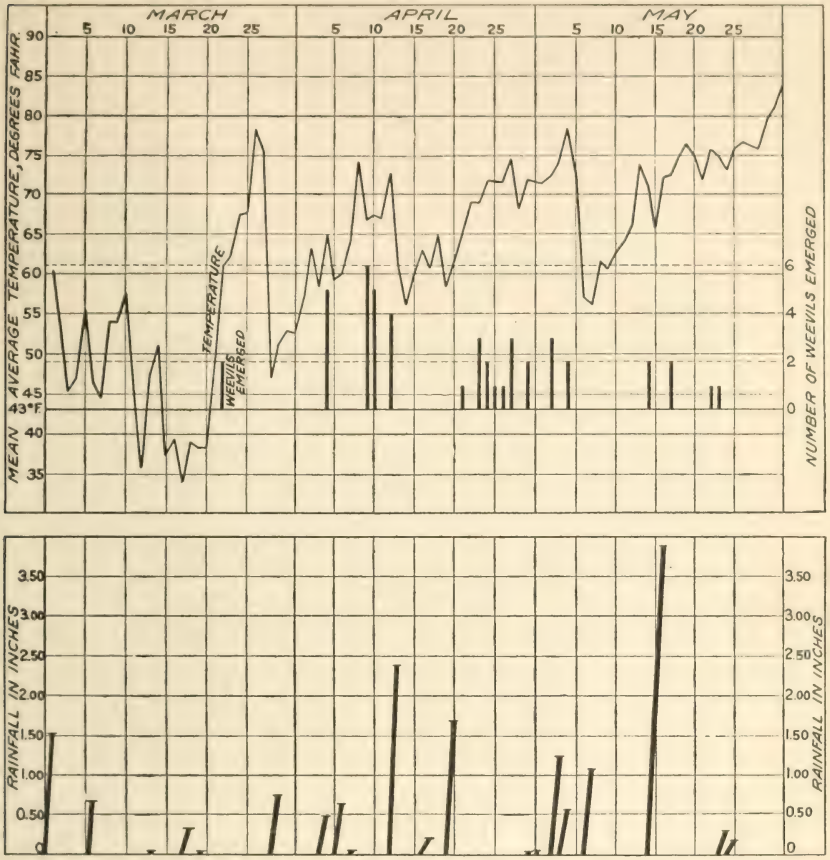



FIG. 2.—Chart showing mean average temperature, rainfall, and weevil emergence, Dallas, Tex., March to May, 1906.

about June 20. It was then easily possible to distinguish between hibernated adults and those which were not more than two or three weeks old. It is probable that the oil paints which were used may have been responsible for the death of many of the weevils marked, since it was hardly possible in the field to apply the paints with the necessary care.

TABLE XXIX.—*Emergence records for one-half-acre field at Victoria, Tex., 1906.*

| Date of examination. | Number of weevils found. | | | | | | | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | Unmarked. | Marked yellow. | | Marked blue. | | Marked red. | | Total number found. | |
| 1906. | | ♂ | ♀ | ♂ | ♀ | ♂ | ♀ | | |
| May 19 | 346 | .... | .... | .... | .... | .... | .... | 346 | Weevils not removed. |
| May 25 | 358 | .... | .... | .... | .... | .... | .... | 358 | Do. |
| May 28.[a] | | | | | | | | | |
| June 3–5 | 492 | .... | .... | .... | .... | .... | .... | 492 | Weevils marked yellow=492. |
| June 13 | 226 | 129 | .... | .... | .... | .... | .... | 355 | Weevils marked blue=226. |
| June 23–July 5 | 165 | 27 | 9 | 18 | 9 | .... | .... | 228 | Weevils marked red=87. |
| July 23–26 | 731 | 3 | 0 | 0 | 1 | 2 | 2 | 739 | Weevils marked white=78. |
| Total | 2,318 | 159 | 9 | 18 | 10 | 2 | 2 | 2,518 | |

[a] Eighty-seven weevils removed from field May 28 for other experimental work.

It is evident from an examination of the number of weevils found that the number in the field increased steadily until after June 5. Between June 5 and 13 a large number of previously marked weevils appeared, all of which were undoubtedly hibernated. The very small number of first-generation weevils which was found upon the examination made between June 23 and July 25 was due primarily to the exceptionally severe hot dry weather which had prevailed for several weeks. The gradual decrease in the number of living hibernated weevils was greater than the increase in the number of first-generation weevils. During the period between the middle of June and the middle of July the plants rapidly increased their fruiting activity and there was a decided decrease in weevil injury. It is interesting to note that in spite of the large number of hibernated weevils occurring in this field, which threatened early in the season to prevent entirely the setting of fruit, the weevil injury and development were so checked by the heat and drought that after the middle of July these plants set fruit rapidly and the field produced an average yield of cotton.

The most plausible explanation of the late period of emergence for weevils found in this field is the existence in its immediate vicinity of a large number of trees which were loaded with long Spanish moss. (See Pl. II, figs. 1, 2.) The explanation of the effect of this moss in producing late emergence from hibernation will be considered more particularly in connection with the cage experiments in hibernation for 1906 to 1907.

## LARGE-CAGE EXPERIMENTS, DALLAS, CALVERT, AND VICTORIA, TEX., 1906–7.

### PLAN OF EXPERIMENTS.

Profiting by the work done during former seasons, plans were made by Mr. W. D. Hunter, in charge of the investigations, for much more careful and extensive work during the winter of 1906–7 than had ever been undertaken. Three localities for the experimental work were selected representing in a general way the northern, central, and southern sections of the State. In these localities, also, much work had previously been done and the results for more than one season could therefore be used in a comparative way. At Dallas, Calvert, and Victoria screen-covered cages were erected, each being 20 feet wide, 50 feet long, and about 6½ feet high. (Pl. VI, figs. 1, 2, and 3.) These cages were divided into ten sections by partitions, each section having a ground area of 100 square feet. The three localities selected offered a considerable range in geographical and climatic conditions. Each section of the cage was provided with a door opening to the outside through which access could be had to a section without disturbing the conditions in any other section. It was planned to provide similar conditions of shelter in corresponding sections and to confine weevils in corresponding sections at as nearly the same date as might be possible in each of the three sections. The weevils used were collected in the immediate locality where they were placed in hibernation. In this way it was anticipated that data might be obtained bearing especially upon the following points:

(1) The effect of the time of entrance into hibernation upon the survival of weevils. In the experiments first started it was necessary to force entrance into hibernation, if possible, or starvation by the destruction of the food supply. The geographical range was expected to increase the interval between the beginning of the experiment in each locality and the time when weevils would normally hibernate.

(2) The effect which the complete destruction of food supply at varying dates might have upon the success of hibernation. For these experiments the shelter conditions were as uniform and as favorable as it was possible to make them in the different localities. It was hoped through these tests to determine the minimum interval which must elapse between the destruction of stalks and the successful hibernation of the weevils.

(3) To determine the effect of exceptionally favorable and unfavorable conditions of shelter upon the hibernation of weevils placed in the cages upon the same date. It was intended that the shelter conditions provided should be so exaggerated as to represent the extremes of conditions which might naturally occur in the field.

(4) To determine the effect which different depths and classes of shelter might exert upon the success of hibernation and also upon the time of emergence and the range of the emergence period.

(5) To test the power of adaptation which the weevils might have acquired to varying climatic conditions by bringing weevils from widely separated localities for comparison with weevils collected at Dallas. In each test similar conditions of food and shelter should exist in each locality.

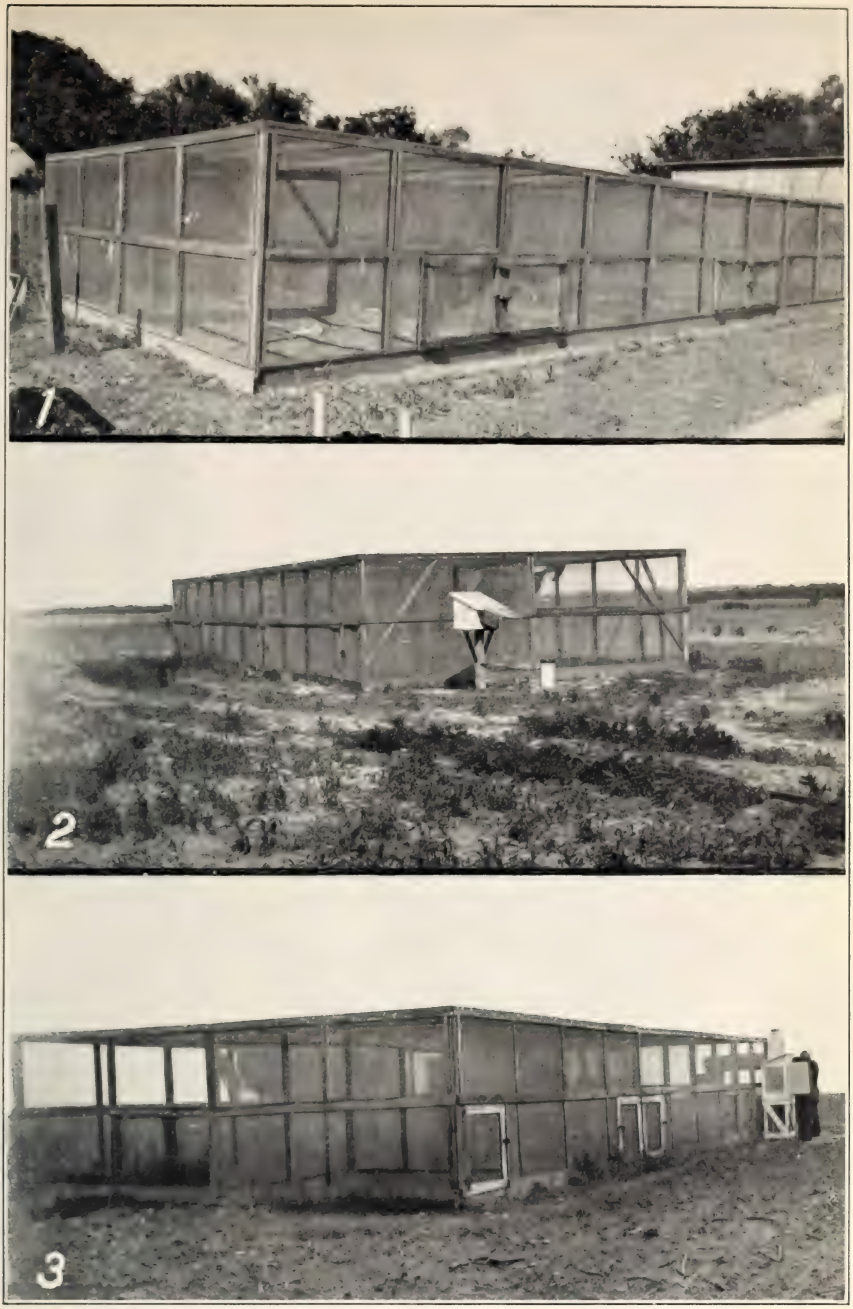
(6) To determine upon a large scale, in very widely separated localities, the proportion of weevils entering hibernation which might survive.

(7) To determine the relation between climatic conditions and the emergence period in each locality. To provide suitable and reliable data for this study, standard Weather Bureau instruments were secured and temperature, humidity, rainfall, and other records were kept in each locality throughout the period covered by the experiments.

(8) To determine the longevity of hibernated weevils, especially after emergence. Since all weevils used in this work were collected promiscuously in the field immediately preceding their confinement in the cages, all figures showing their longevity must be based either upon the date when they were placed in hibernation or upon the date of their emergence. In the latter case it would be distinguished as longevity after emergence.

It was planned to use from 2,500 to 3,000 weevils in each section of the cages, although difficulties in the collection of the desired number for the particular dates when experiments were to be started occasionally caused some variation in this number. Adult weevils only were used in sections 1 to 9, inclusive, in each cage, while in section 10 the hibernation of weevils in bolls was tested. One-half of the bolls were buried under 2 inches of dirt. The other half were exposed upon the surface of the ground. (Pl. X, fig. 1.)

It is generally understood that the principal factor producing a hibernation period is the lower temperature occurring during the fall and winter months. In its effect upon the survival during this period moisture is also an important factor. As a rule, in studies of these factors investigators have been obliged to rely upon the climatic reports published by the United States Weather Bureau for the particular locations desired. It happens frequently, however, that there may be no report from the Weather Bureau for the particular locality desired. Both temperature and rainfall are liable to considerable variation within comparatively short distances. In order that the data for these studies of the hibernation of the boll weevil might be complete and thoroughly reliable, we have kept full climatic records in the immediate vicinity where experiments and cage obser-




CAGES FOR HIBERNATION EXPERIMENTS IN TEXAS, 1906-7.

Fig. 1.—Dallas, Tex., cage on flat, black-waxy land. Fig. 2.—Calvert, Tex., cage on slightly sloping, sandy land in post-oak region. Fig. 3.—Victoria, Tex., cage on sandy-loam slope between bottom and upland. (Original.)

vations have been made. The instruments used are of standard Weather Bureau type (Pl. I, fig. 1) and, as the records extend over several years, reliable data have been secured upon the following climatic factors which may affect hibernation: Maximum and minimum temperatures supplemented by a continuous temperature record made by a recording thermograph; the actual rainfall as measured in a standard type of rain gauge; the atmospheric moisture existing at 8 or 9 o'clock a. m. and 5 to 6 o'clock p. m., supplemented by a continuous record of the moisture in the air furnished by a hygrograph.

TABLE XXX.—*Outline of hibernation experiments in 1906–7.*

| No. of section. | Date of starting experiments in 1906. | | | Character of shelter supplied. | Food supply. |
|---|---|---|---|---|---|
| | Dallas. | Calvert. | Victoria. | | |
| 1 | Oct. 13 | Oct. 13 | Oct. 25 | Leaves and grass, 4 to 5 inches | All food removed after two days. |
| 4 | Oct. 16 | Oct. 19 | ...do | ...do | Stalks cut down and left to dry. |
| 2 | Oct. 19 | Nov. 26 | Oct. 28 | ...do | All food removed after two days. |
| 7 | Oct. 25 | Oct. 25 | Nov. 6 | Spanish moss hung on string at top of cage; loose bark on ground. | Stalks cut down and allowed to dry. |
| 8 | Oct. 31 | Oct. 31 | Nov. 10 | Leaves and grass 4 to 5 inches deep. | All food removed after two days |
| 5 | Nov. 6 | Nov. 5 | Nov. 14 | ...do | Cotton cut down and allowed to dry. |
| 3 | Nov. 12 | Nov. 14 | Nov. 21 | Leaves and grass, 2 inches | Do. |
| 9 | ...do | Nov. 12 | ...do | Leaves and grass, 10 inches | Do. |
| 6 | Nov. 28 | Nov. 25 | Nov. 28 | Ground absolutely bare | No food supply. |
| 10 | Dec. 6 and 10. | Dec. 3 | Nov. 29 | (a) | |

a In this section, 3 bushels of probably infested bolls were exposed on the surface of the ground in one half of cage, and 3 bushels were buried under 2 inches of dirt in the other half.

The dates given in Table XXX are the actual dates of beginning the experiment in each locality. The arrangement of the experiments shown in the table is primarily chronological, without regard to the sequence in the number of sections. Some knowledge of the plan of this work is essential to a clear understanding and a correct interpretation of the results obtained from it.

## CLIMATIC CONDITIONS PRODUCING HIBERNATION AND ACTIVITY OF WEEVILS DURING NORMAL HIBERNATION PERIOD.

The climatic records are started with October 1, 1906, in order to show a comparison between temperature conditions under which weevils are normally very active with those under which they become inactive. The termination of what is considered as being the hibernation period is rather arbitrarily set at the time when weevils begin to emerge in considerable numbers. It should be stated that in each locality the climatic records for the winter of 1906 were very unusual. The principal points of variation will be noted in subsequent paragraphs in their most important connections. In each chart (figs. 3–5) showing temperature conditions it has been deemed advisable to show only the line representing the mean average temperature.

While it is probable that a study of maximum and minimum temperatures is really more accurate, from a scientific point of view, the mean average temperature, representing one-half of the sum of the maximum and minimum for each day will be sufficiently exact and a more simple manner of expressing the relationship existing between temperature and weevil activity. The significance of the term "effective temperature" has previously been explained (p. 24). Upon the temperature charts the line representing 43 degrees is therefore exceptionally emphasized. Wherever the temperature line is above this point it represents effective temperature. Whenever it falls below the 43-degree line it is possible that frosts may occur if other atmospheric conditions are coincidently favorable.

Whenever the minimum is noted to be 32 degrees or below, the actual temperature occurring is given in its appropriate place upon the record. When the temperature rises above 80 degrees, establishing a new maximum, the occurrence is also shown by the actual record given upon the charts.

Since it is impossible for weevil emergence to occur at any temperature below 43 degrees, that point is considered as initial in the lines giving the records of the activity of weevils. The actual number of weevils found active at various dates is shown at the top of the line in each case.

### ENTRANCE INTO HIBERNATION.

In each locality there occurred a considerable decrease in temperature during the month of October, the minimum being reached about the 31st. This, however, was not sufficiently cold to cause weevils to hibernate in considerable numbers. During the following two weeks the temperature ranged as high as the average for October. After November 15, however, there occurred a very marked fall of temperature, the minimum even as far south as Victoria establishing itself at about 25 to 27 degrees. All cotton was killed by this freeze. The count of weevils found active early in November indicated merely that few weevils had entered hibernation at that time. Further counts, made about November 30, showed that even so severe a drop in temperature as had occurred did not immediately drive weevils into hibernation. During the succeeding two or three weeks the temperature again ranged fully as high as during October, and apparently many weevils which had sought shelter after the freeze of the night of November 19 again became active. This was indicated by the large number of weevils found active at Calvert and Victoria about December 10. About the middle of December another period of low temperature occurred, which was followed by decreased activity among the weevils, many of which did not, even then, seek shelter. During the first three weeks of January the exceptionally warm weather experienced throughout Texas drew a considerable number

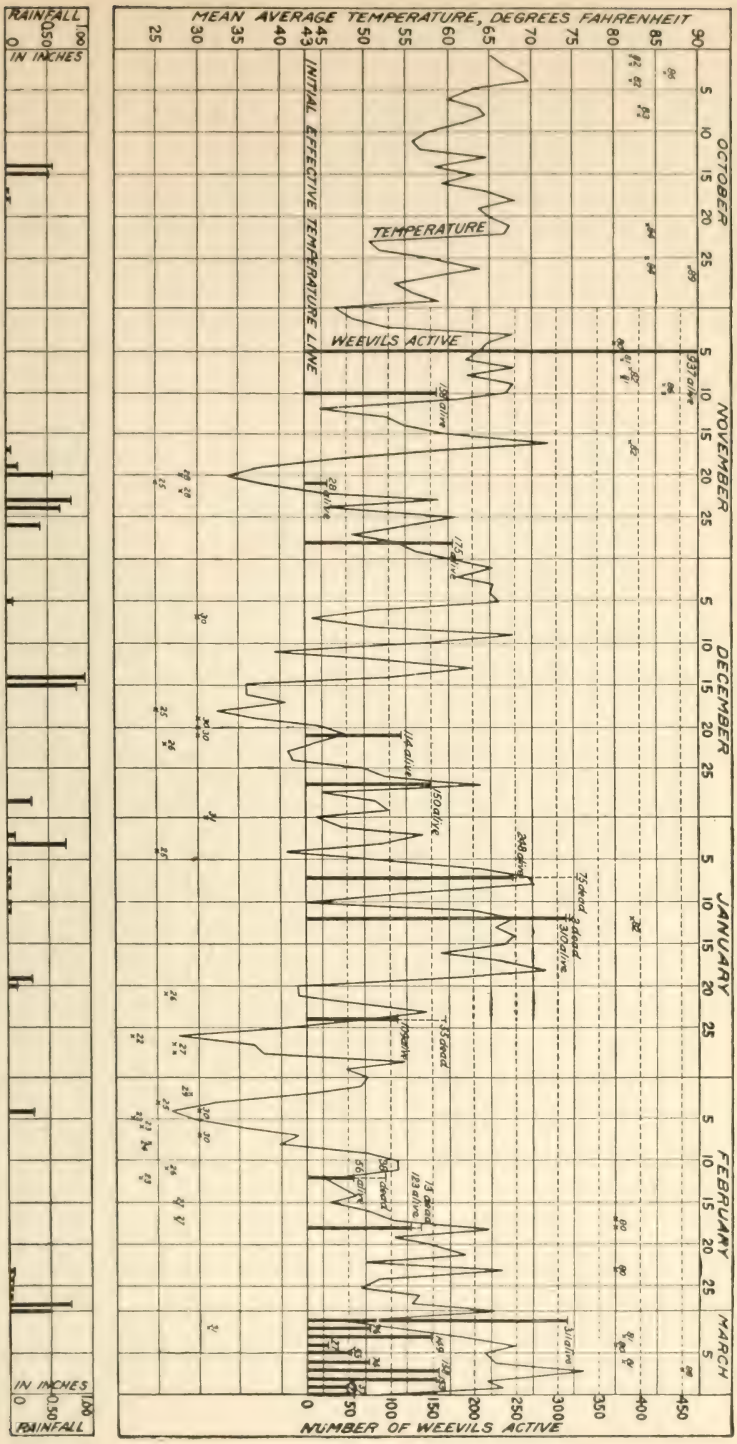



FIG. 3.—Chart showing mean average temperature, rainfall, and weevil activity, Dallas, Tex., October, 1906, to March, 1907.

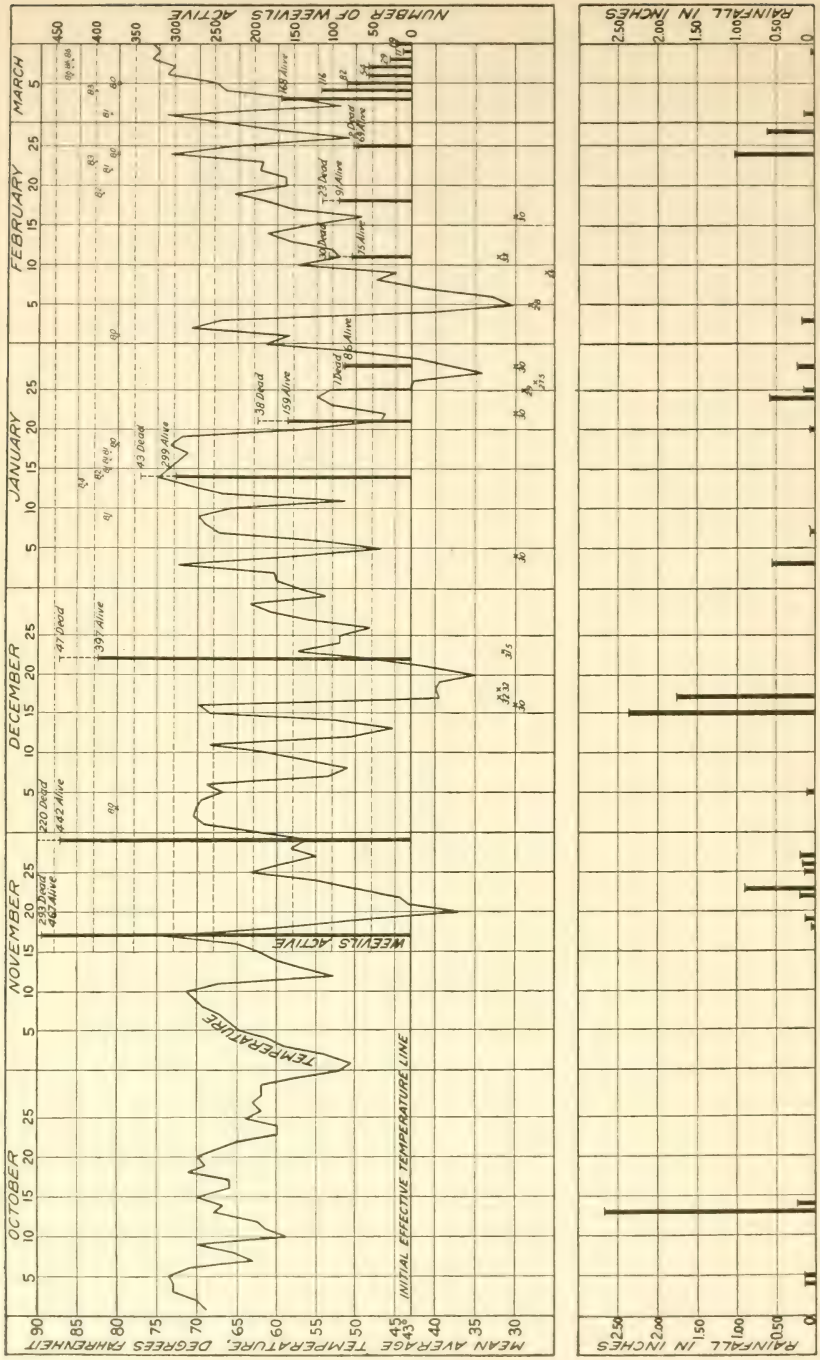



Fig. 4.—Chart showing mean average temperature, rainfall, and weevil activity, Calvert, Tex., October, 1906, to March, 1907.

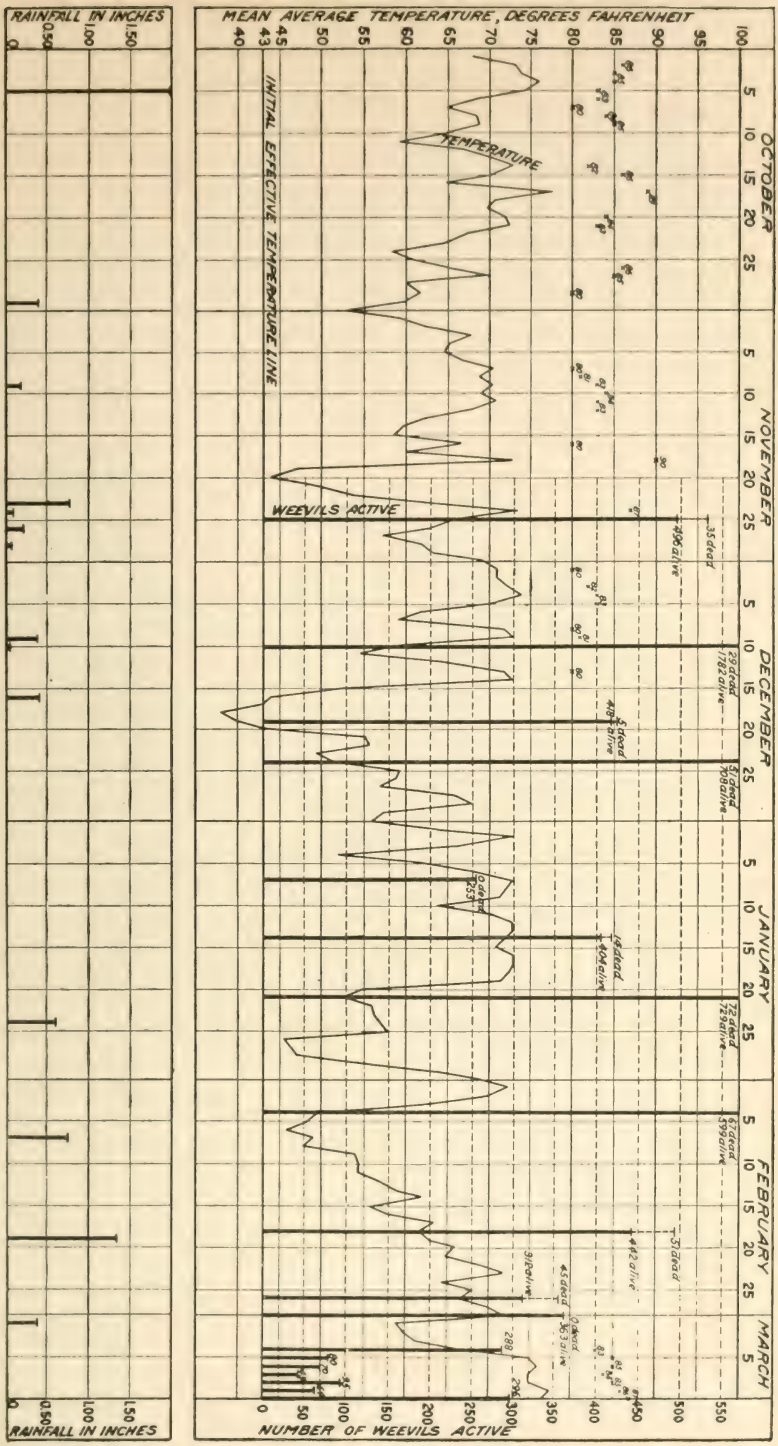



FIG. 5.—Chart showing mean average temperature, rainfall, and weevil activity, Victoria, Tex., October, 1906, to March, 1907.

of weevils from shelter. During the last week of January and the first week of February the lowest temperatures of the winter occurred at Dallas and Calvert. The counts made immediately after this period showed the smallest number of active weevils recorded at any time during the winter for those two localities. At Victoria the temperature was not sufficiently low to produce any marked decrease in weevil activity. During the remainder of February there was a rather steady rise in temperature throughout the State and many weevils continued active. The figures show that during the last week of the month considerable numbers were emerging from their winter shelter; and beginning with March 1 the period of general emergence is considered to have begun.

While these three charts show plainly the conditions existing during the winter of 1906–7, proving beyond question that during this season there was no such thing as complete hibernation of the boll weevil in Texas, it must not be understood that this is frequently the case. No other such season has occurred since the weevil entered Texas. As a rule, hibernation is complete during the period of from four to six months. It is certain that weevils may continue their activity throughout the season wherever climatic conditions are not sufficiently severe to entirely destroy the growth of cotton.

### ACTIVITY DURING NORMAL PERIOD OF HIBERNATION.

The general impression as to the activity of weevils during the normal period of hibernation has been shown in figures 3 to 5. A summary of the records for the three locations, with the temperature conditions prevailing at the time of each examination, is shown in Table XXXI.

TABLE XXXI.—*Activity during normal hibernation period, 1906–7.*

DALLAS.

| Date. | Weevils counted in section— | | | | | | | | | | Total weevils counted. | Temperature. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | | Max. | Mean. |
| 1906. | | | | | | | | | | | | °F. | °F. |
| Nov. 5 | 230 | 290 | ..... | 102 | ..... | ..... | 315 | ..... | ..... | ..... | 937 | 79 | 64.0 |
| Nov. 10 | 62 | 96 | | | | | | | | | 158 | 86 | 67.5 |
| Do | 4 | 12 | ..... | ..... | 12 | ..... | ..... | ..... | ..... | ..... | 28 | 51 | 38.0 |
| Nov. 28 | ..... | ..... | 130 | 1 | 33 | ..... | 4 | 7 | ..... | ..... | 175 | 62 | 54.0 |
| Dec. 21 | 5 | 23 | 19 | 2 | 15 | ..... | 9 | 11 | 12 | 18 | 114 | 66 | 48.0 |
| Dec. 27 | 8 | 10 | 48 | 5 | 20 | ..... | 8 | 7 | 19 | 25 | 150 | 73 | 64.0 |
| 1907. | | | | | | | | | | | | | |
| Jan. 1 | 9 | 18 | 39 | 7 | 28 | ..... | 13 | 11 | 43 | 80 | 248 | 75 | 69.5 |
| Jan. 12 | 15 | 24 | 68 | 15 | 33 | ..... | 15 | 15 | 55 | 70 | 310 | 82 | 68.0 |
| Jan. 24 | 4 | 5 | 25 | 3 | 17 | 21 | 4 | ..... | 16 | 14 | 109 | 73 | 48.5 |
| Feb. 12 | 1 | 4 | 5 | 2 | 9 | 4 | 4 | 1 | 22 | 2 | 54 | 64 | 45.0 |
| Feb. 19 | 3 | 4 | 7 | 3 | 21 | 7 | 14 | 5 | 50 | 9 | 123 | 80 | 65.0 |
| Total | 341 | 486 | 341 | 140 | 188 | 32 | 386 | 57 | 217 | 218 | [a]2,406 | ..... | ..... |

[a] This total represents 7.8 per cent of all the weevils put in the cage.

TABLE XXXI.—*Activity during normal hibernation period, 1906–7*—Continued.

CALVERT.

| Date. | Weevils counted in section— | | | | | | | | | | Total weevils counted. | Temperature. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | | Max. | Mean. |
| 1906. | | | | | | | | | | | | °F. | °F. |
| Nov. 17 | 17 | ..... | ..... | 28 | 233 | ..... | 28 | 161 | ..... | ..... | 467 | ..... | ..... |
| Nov. 29 | 3 | 214 | 55 | 9 | 6 | ..... | 6 | 10 | 139 | ..... | 442 | ..... | ..... |
| Dec. 22 | 4 | 47 | 30 | 4 | 8 | 217 | 0 | 17 | 69 | 1 | 397 | 60 | 48.0 |
| 1907. | | | | | | | | | | | | | |
| Jan. 14 | 11 | 68 | 41 | 12 | 10 | 90 | 3 | 12 | 50 | 2 | 299 | 82 | 70.0 |
| Jan. 21 | 3 | 30 | 22 | 7 | 7 | 63 | 2 | 4 | 20 | 1 | 159 | 62 | 47.0 |
| Jan. 28 | 1 | 13 | 7 | 1 | 3 | 37 | 1 | 5 | 17 | 1 | 86 | 56 | 39.0 |
| Feb. 11 | 3 | 12 | 5 | 0 | 1 | 28 | 1 | 4 | 21 | 0 | 75 | 75 | 52.0 |
| Feb. 18 | 1 | 13 | 6 | 0 | 2 | 43 | 2 | 2 | 22 | 0 | 91 | 79 | 62.0 |
| Feb. 25 | 3 | 10 | 5 | 0 | 2 | 36 | 1 | 1 | 11 | 0 | 69 | 74 | 65.0 |
| Total | 46 | 407 | 171 | 61 | 272 | 514 | 44 | 216 | 349 | 5 | [a] 2,085 | ..... | ..... |

VICTORIA.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1906. | | | | | | | | | | | | | |
| Nov. 25 | 133 | 204 | ..... | 159 | ..... | ..... | ..... | ..... | ..... | ..... | 496 | 74 | 66.5 |
| Dec. 10 | ..... | ..... | 345 | ..... | 504 | ..... | 64 | 546 | 323 | ..... | 1,782 | 73 | 59.5 |
| Dec. 19 | ..... | ..... | 163 | ..... | ..... | ..... | ..... | ..... | 236 | 19 | 418 | 47 | 40.0 |
| Dec. 21 | 62 | 95 | ..... | 66 | 186 | 81 | 18 | 200 | ..... | ..... | 708 | 65 | 51.5 |
| 1907. | | | | | | | | | | | | | |
| Jan. 7 | ..... | ..... | 108 | ..... | ..... | ..... | ..... | ..... | 134 | 11 | 253 | 77 | 73.0 |
| Jan. 14 | 147 | 89 | ..... | 62 | ..... | 106 | ..... | ..... | ..... | ..... | 404 | 77 | 72.0 |
| Jan. 21 | 68 | 50 | 123 | 27 | 69 | 76 | 16 | 106 | 189 | 5 | 729 | 66 | 52.5 |
| Feb. 4 | 48 | 55 | 89 | 40 | 85 | 46 | 43 | 67 | 123 | 3 | 599 | 60 | 50.0 |
| Feb. 18 | 55 | 40 | 91 | 21 | 65 | 46 | 18 | 29 | 74 | 3 | 442 | 74 | 62.0 |
| Feb. 26 | 49 | 28 | 75 | 13 | 66 | 31 | 50 | ..... | ..... | ..... | 312 | 70 | 66.5 |
| Total | 562 | 561 | 994 | 388 | 975 | 386 | 209 | 948 | 1,079 | 41 | [b] 6,143 | ..... | ..... |

[a] This total represents 10.5 per cent of all the weevils put in the cage.
[b] This total represents 27.7 per cent of all weevils put in the cage.

It is hardly probable that a majority of the weevils may have been counted upon two or more dates, but the fact that dead weevils were found clinging to the wire (Pl. VII, fig. 1) at the time of each examination indicates a considerable mortality among the active weevils and that the places of the dead ones in successive counts were taken by weevils which had become active since the preceding examination. The percentages of active weevils for the three localities show a rather significant difference, and are given for the sake of this comparison without presuming to state correctly the actual percentage of weevils placed in hibernation which remained active during the winter in the respective localities. At Dallas the 2,406 weevils counted during the winter constitute 7.8 per cent of the total number placed in hibernation. At Calvert the 2,085 active weevils constitute 10.5 per cent of the 19,408 placed in the cage. At Victoria the 6,143 active weevils constitute 27.7 per cent of the 22,463 in the experiment. Since approximately the same number of examinations were made in each locality the differences in percentage indicate in a general way the relative activity in these sections of

the State. Thus at Dallas 8, at Calvert 11, and at Victoria 28 out of every 100 weevils placed in hibernation might have been active during the winter. Of course, it is likely that many weevils were counted twice. On the other hand, to counterbalance this duplication in the number recorded, it should be stated that undoubtedly many weevils were active at intervals between the counts which were either upon the ground or had returned to the ground before the examinations were made. Only those weevils which were found crawling upon the wire covering of the cage were recorded. The temperature conditions as shown for the dates of examination indicate that there would be no physiological difference in normal weevil activity upon those dates. The sectional totals indicate that variations in the class of shelter in the different sections exerted little, if any, effect upon the activity of weevils during the winter, with the exception that Spanish moss seemed to keep more weevils from becoming active than did any other shelter.

## WINTER ACTIVITY.

In most instances when the active living weevils were recorded those which were found dead clinging to the wire were collected and counted for each section. Undoubtedly a great many weevils fell from the screen before or after dying, so that the records are very conservative in showing the mortality occurring between examinations. These records should be considered in connection with weevil activity, since the collection of dead stages prevented their accumulation upon the wire, and the number found at each examination must be considered of those surviving and remaining on the wire from a preceding examination and those which emerged subsequently thereto.

TABLE XXXII.—*Summary of winter activity as shown by counts of dead weevils.*

DALLAS.

| Date. | Number of dead weevils found in section— | | | | | | | | | | Total number of dead weevils. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | |
| 1907. | | | | | | | | | | | |
| January 5 | 2 | 3 | 4 | 1 | 34 | ..... | 10 | 7 | 10 | 4 | 75 |
| January 12 | 0 | 1 | ..... | ..... | 2 | ..... | ..... | ..... | ..... | ..... | 3 |
| January 24 | 2 | 2 | 2 | ..... | 2 | [a] 672 | ..... | ..... | 2 | 5 | [a] 687 |
| February 12 | 1 | 3 | 4 | 1 | 5 | 7 | 3 | 1 | 6 | 7 | 38 |
| February 19 | ..... | ..... | 3 | 1 | 3 | 1 | 1 | ..... | 3 | 1 | 13 |
| Total | 5 | 9 | 13 | 3 | 46 | 680 | 14 | 8 | 21 | 17 | [b] 816 |

[a] Of these, 622 were on cloth on ground, having fallen from the wire.
[b] This total represents 2.6 per cent of all the weevils put in the cage.

SHELTER CONDITIONS, DALLAS, TEX., CAGE.

Fig. 1.—Active weevils trying to escape through wire on October 20, 1906. Fig. 2.—Section 1, in which weevils were placed October 13, 1906, 2.61 per cent surviving. Fig. 3.—Section 4, started October 16, 1906, 4.07 per cent surviving. (Original.)

TABLE XXXII.—*Summary of winter activity as shown by counts of dead weevils*—Con.

CALVERT.

| Date. | Number of dead weevils found in section— | | | | | | | | | | Total number of dead weevils. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | |
| 1906. | | | | | | | | | | | |
| November 17 | 121 | ..... | ..... | 36 | 83 | ..... | 6 | 47 | ..... | ..... | 293 |
| November 29 | 14 | 2 | 101 | 7 | 39 | 1 | 2 | 20 | 34 | ..... | 220 |
| December 22 | 1 | 3 | 16 | 7 | 5 | 2 | 0 | 4 | 7 | 2 | 47 |
| 1907. | | | | | | | | | | | |
| January 14 | 5 | 4 | 3 | 2 | 5 | 10 | 0 | 3 | 10 | 1 | 43 |
| January 21 | 0 | ..... | 12 | ..... | 5 | 12 | 0 | 0 | 6 | 0 | 35 |
| January 28 | 1 | ..... | ..... | 0 | ..... | ..... | 0 | 0 | ..... | 0 | 1 |
| February 11 | 0 | 5 | 5 | 2 | 0 | 12 | 0 | 3 | 3 | 0 | 30 |
| February 18 | 1 | 4 | 3 | 0 | 0 | 4 | 0 | 2 | 9 | 0 | 23 |
| February 25 | 0 | ..... | 1 | 0 | 0 | 0 | 1 | 0 | ..... | 0 | 2 |
| Total | 143 | 18 | 141 | 54 | 137 | 41 | 9 | 79 | 69 | 3 | [a] 694 |

VICTORIA.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1906. | | | | | | | | | | | |
| November 25 | 8 | 13 | ..... | 14 | ..... | ..... | ..... | ..... | ..... | ..... | 35 |
| December 10 | ..... | ..... | 2 | ..... | 6 | ..... | 2 | 16 | 3 | ..... | 29 |
| December 19 | ..... | ..... | 3 | ..... | ..... | ..... | ..... | ..... | 2 | 0 | 5 |
| December 24 | 3 | 7 | ..... | 19 | 11 | ..... | 5 | 6 | ..... | ..... | 51 |
| 1907. | | | | | | | | | | | |
| January 7 | ..... | ..... | 0 | ..... | ..... | ..... | ..... | ..... | 0 | 0 | 0 |
| January 14 | 3 | 4 | ..... | 5 | ..... | 2 | ..... | ..... | ..... | ..... | 14 |
| January 21 | 6 | 10 | 12 | 6 | 12 | 4 | 2 | 12 | 5 | 2 | 71 |
| February 4 | 9 | 8 | 9 | 2 | 10 | 1 | 2 | 14 | 11 | 1 | 67 |
| February 18 | 6 | 2 | 7 | 8 | 4 | 1 | 0 | 12 | 11 | 0 | 51 |
| February 26 | 9 | 11 | 4 | 5 | 11 | 5 | 0 | ..... | ..... | ..... | 45 |
| Total | 44 | 55 | 37 | 59 | 54 | 13 | 11 | 60 | 32 | 3 | [b] 368 |

[a] This total represents 3.6 per cent of all the weevils put in the cage.
[b] This total represents 1.7 per cent of all the weevils put in the cage.

In the section of the table containing the records for Dallas the large number of weevils found dead in section 6 on January 24, 1907, may be explained by the statement that no previous collection of dead weevils had been made in this section. All but 50 of the weevils found were upon cheesecloth stretched horizontally across the section above the ground. The full number is included merely to indicate the proportion of weevils which probably fall to the ground upon dying. In this section less than 20 per cent remained upon the screen, and it is reasonable to suppose that a similar proportion may have existed in other sections. The percentage of mortality in each place is much smaller than the percentage of living weevils. Upon the charts shown in figures 3 to 5 the number of dead collected is indicated by a broken line extending beyond the line representing the number of living weevils.

### ACTIVITY AS SHOWN BY DEVELOPMENT DURING NORMAL HIBERNATION PERIOD.

Under the heading "Stages entering hibernation" the principal data bearing upon developmental activity during the winter have been given. (See pp. 13 and 14.) Additional data have also been given in connection with "Shelter during hibernation." (See Table VII, p. 26; also Table IX, p. 28.) To these records for seasons preceding 1906–7 may be added the results of an experiment in collection of infested squares during this season. On November 23, 1906, Mr. J. D. Mitchell collected 100 fallen squares which were supposed to be infested. These were placed in the small cage under shelter and out of the reach of sunshine. On February 10, 1907, he found that 45 squares showed weevil emergence hulls, and the full number of adults was found; however, all were dead at that time. An examination of the remainder of the squares revealed but one dead larva. The others, apparently, had contained no weevil stages. Exceptionally warm weather had prevailed during December and January, as has been shown in figure 5. This had enabled the weevils to complete their development and emerge, but all had starved to death in the absence of any food supply.

Some very interesting facts are also brought out by a closer study of the records in connection with section 10 of each cage. As has been shown, the experiment in these sections consisted of the collection of large numbers of unopened bolls probably infested. Several of the bolls were buried under 2 inches of dirt and the remainder were exposed upon the surface of the ground (Pl. X, fig. 1). No partition was inserted to separate the weevils emerging from these two lots of bolls, but in the case of section 10 at Dallas the first lot of bolls was buried and a considerable period elapsed before the balance of the bolls, which were left upon the surface, was placed in the cage. It was estimated that 3,000 bolls were buried at a uniform depth of 2 inches under cover of heavy black soil. An examination of 100 bolls showed 8 recently transformed but unemerged adults in the bolls and 8 adults which had emerged were hibernating within the protection afforded by the bolls. On this basis it appears that about 480 weevils were buried in this lot of 3,000 bolls, half of them being unemerged adults and half hibernating adults. No other material was placed within this section, so that all weevils which were subsequently found upon the screen must necessarily have found their way through the 2 inches of soil under which the bolls were buried. Counts made before the bolls to be placed on the surface were put into the cage showed that 65 weevils at least had escaped from the bolls to the screen forming the cage. This shows that fully 13.5 per cent of all the weevils buried, emerged and unemerged, had

succeeded in escaping. Undoubtedly part of these had left their cells in the bolls after they were buried, as it is very likely that the burial of the bolls in moist soil may soften the hulls so as to enable the weevils to escape through them as readily as though they remained dry upon the surface of the ground.

### ACTIVITY IN THE FIELD DURING NORMAL HIBERNATION PERIOD.

For a number of years it has been known that, in southern Texas especially, weevils may frequently be found moving actively in the field during the winter, but the observations made during the season of 1906–7 extended the range of such occasional activity even in northern Texas.

TABLE XXXIII.—*Outdoor activity of weevils during winter of 1906–7.*

| Locality. | Date. | Weevils found. | Sprout plants examined. | Remarks. |
|---|---|---|---|---|
| | 1907. | | | |
| Dallas, Tex | Jan. 1 | 1 | ..... | Found on awning rope. |
| Do | Jan. 11 | 1 | ..... | Found on window screen; temperature 74° F. |
| Do | Feb. 12 | 1 | ..... | Found on outside of hibernating cage; temperature 75° F. |
| College Station, Tex | Feb. 22 | 1 | ..... | Do. |
| Do | Jan. 17 | 2 | ..... | Feeding on sprout cotton. |
| | 1906. | | | |
| Victoria, Tex | Dec. 29 | 9 | ..... | When given sprouts, all were feeding in 80 minutes; temperature 82° F. |
| Do | ...do..... | 10 | ..... | When given sprouts, all were feeding in 45 minutes; temperature 82° F. |
| | 1907. | | | |
| Do | Jan. 8 | 9 | (*a*) | Mean temperature, January 1-8,=67.76° F. |
| Do | Jan. 9 | 20 | (*b*) | On black land. |
| Do | Jan. 12 | 7 | 6 | |
| Do | Jan. 16 | 1 | 50 | 10 weevils in bolls on the same plant. |
| Do | ...do..... | 2 | 30 | |
| Do | Jan. 17 | 4 | 8 | |
| Do | Jan. 18 | 1 | 17 | |
| Do | Feb. 14 | 1 | 25 | Upland sprouts not killed as in bottoms. |
| Do | Feb. 21 | 3 | 50 | Very dry for sprout growth. |

*a* Record not kept, though plants were examined.
*b* Sprout cotton on six farms examined.

From the Victoria records it appears that between January 8 and February 21, at a time when weevils should normally have been in complete hibernation, 48 adults were found feeding on about 200 sprout plants. This record is unique for the United States, and a similar activity in the field may not be duplicated except under very rare conditions.

## EMERGENCE FROM HIBERNATION, 1907.

As is plainly shown by figures 3 to 5, the actual period of general emergence from hibernation began in each locality about February 20. As has been previously stated, the actual date of the beginning of emergence can not be positively given. It can be better expressed as a period of "beginning emergence," and for this reason this period seems to lie between February 20 and March 1. Owing to the excep-

tional earliness of the season preparations for the regular observations upon emergence from hibernation were not sufficiently complete for beginning the work until March 1 and in each locality this date may very reasonably be considered as the beginning of the emergence period.

Previous experience having demonstrated the necessity of keeping the records upon this work according to a uniform system in each locality, the preparations were much more elaborately made than for any previous work. Comprehensive forms upon which the records might be entered with a minimum of labor were prepared covering five distinct divisions of the work: (1) Meteorological record; this record covered maximum and minimum temperatures, atmospheric humidity, rainfall, sunshine or cloudiness, and winter conditions. (2) Emergence record; this record showed the emergence in each section for each date. The records for one week were placed upon a card so that the totals for emergence for each day, and also for each section for each week, could be very readily ascertained. (3) Section record; this covered in more detail the emergence in each section and indicated the sex of emerging weevils and what disposition was made of them, in such a way that their records could be followed until the time of death. (4) Longevity records for fed weevils. (5) Longevity records for unfed weevils.

This systematization of the record work has proved an invaluable help in compiling the results of this extensive series of observations. The general facts regarding the relationship existing between climatic conditions and weevil emergence are indicated graphically in figures 6 to 8. The most important conclusions upon special points can only be shown by special arrangements of the data in each case. These tables have been made as concise as seems possible. Practically each line in the tables expresses only the summary of a large number of compiled records. The magnitude of the work involved in the completion of such data can be appreciated only by one who has undertaken a similar task.[a]

## RELATIONSHIP OF EMERGENCE FROM HIBERNATION TO CLIMATIC CONDITIONS.

Figures 6 to 8 have been prepared in the same form as figures 3 to 5, since they express a continuation of similar facts.

In former reports,[b] dealing especially with the life history of the boll weevil, it was stated that emergence began about the time when the mean temperature rose above 60° F. The more complete

[a] The senior author desires to express particular appreciation of the great amount of detail work which has been done by the junior author (Mr. W. W. Yothers) in the preparation of the summaries covering this work.

[b] U. S. Dept. Agr., Bur. Ent., Buls. 45 and 51.

records now at hand indicate that emergence may take place whenever the mean average temperature exceeds 55° F. It is certain that weevils may be active at a temperature considerably lower than this, but the records do not indicate that there is a general

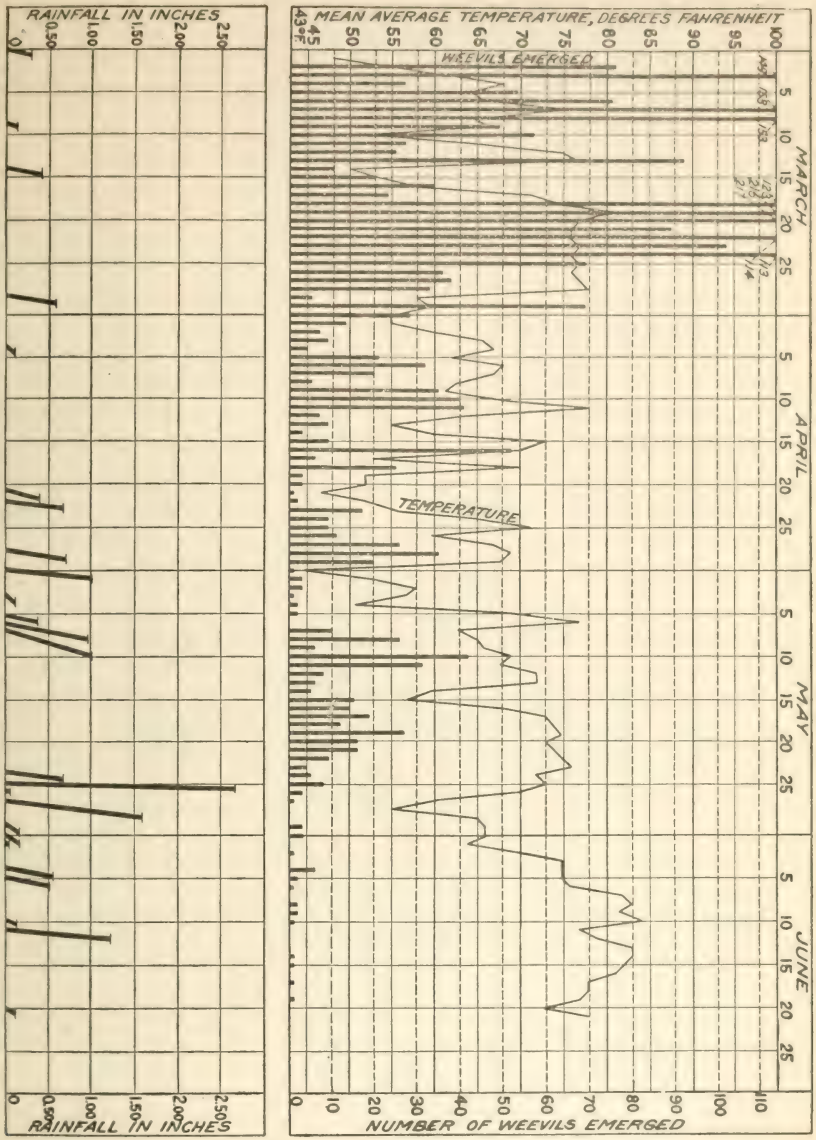



FIG. 6.—Chart showing mean average temperature, rainfall, and emergence from hibernation, Dallas, Tex., March to June, 1907.

emergence from hibernation at a lower temperature. After having left their winter quarters, weevils may continue active at considerably lower temperatures than are required to draw them out from their shelter. This statement may, in part at least, explain the continued

activity of weevils during the winter of 1906–7 and the early beginning for the period of emergence for that season.

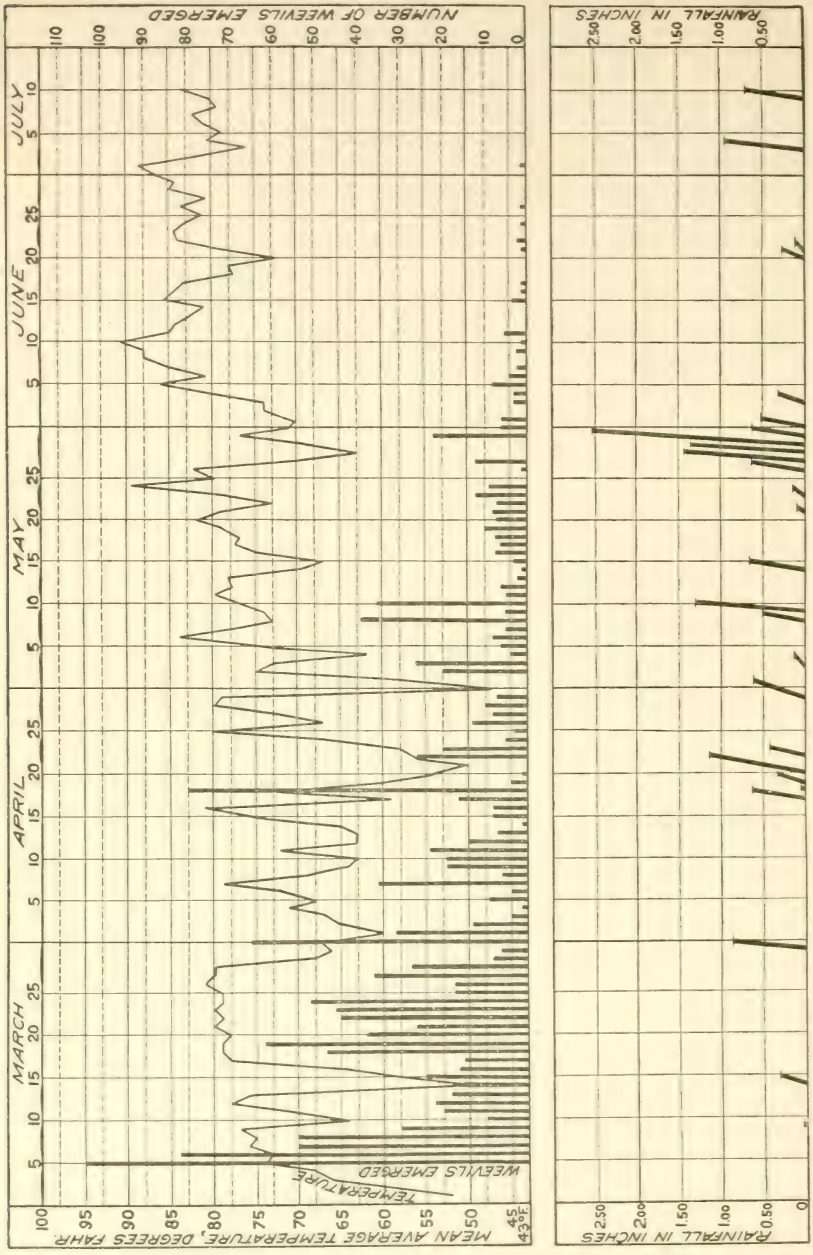



Fig. 7.—Chart showing mean average temperature, rainfall, and weevil emergence, Calvert, Tex., March to June, 1907.

A comparison of figures 6, 7, and 8 indicates that the period of greatest emergence in each locality occurred during March, 1907. The abnormal nature of temperature conditions is shown by the fact that

at Dallas the mean average temperature for the month was over 11 degrees above the normal. At Calvert the departure was about the

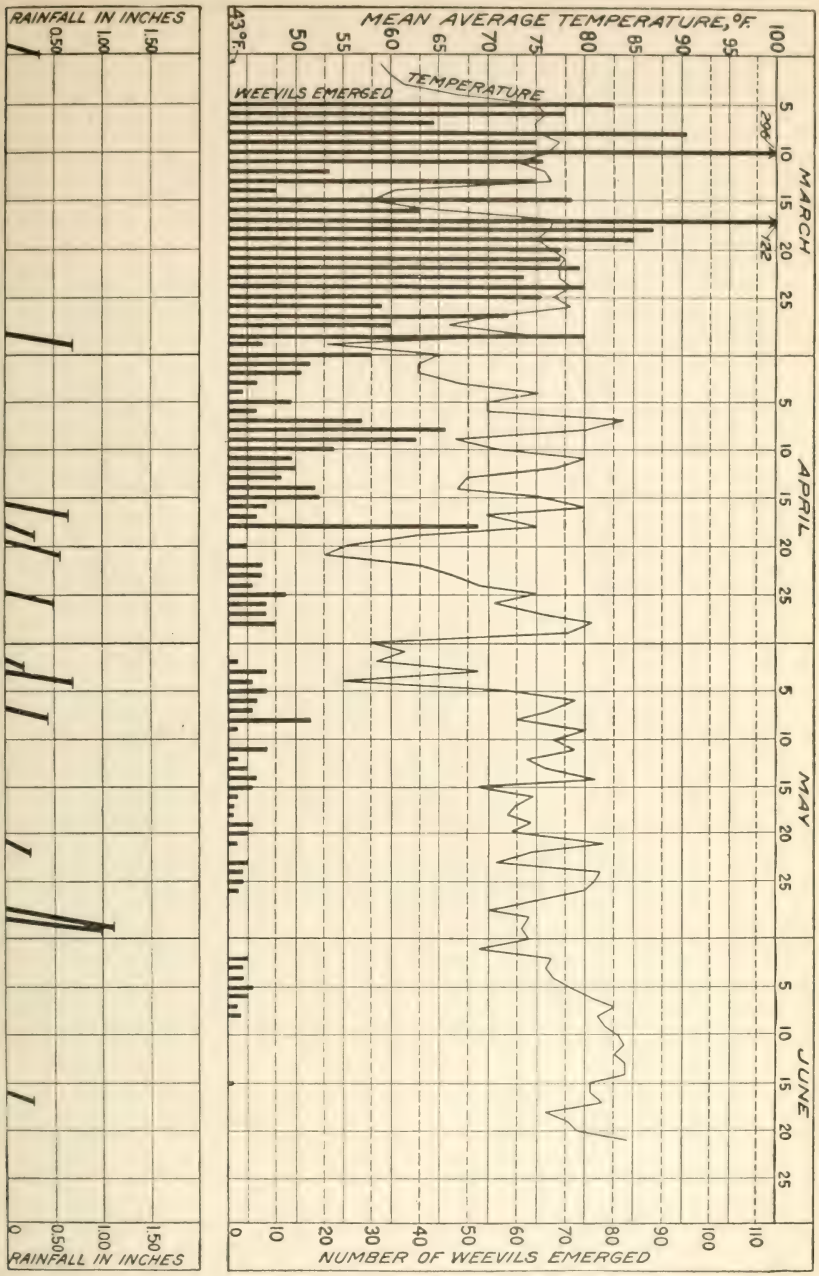



FIG. 8.—Chart showing mean average temperature, rainfall, and weevil emergence, Victoria, Tex., March to June, 1907.

same, and at Victoria it was but slightly less than 10 degrees above normal. Such high temperatures do not often occur before the latter part of April and the 1st of May. The temperature for April was

unusually unfavorable, but in all sections it ranged from 3 to 5 degrees below the normal. This decrease was not, however, sufficient to check the emergence of weevils, although undoubtedly it served to extend the period of emergence in an unusual degree. The abnormal nature of the temperature conditions for the spring of 1907 may be understood from a comparison of the mean monthly temperatures for these four months in each case. The normal is determined by the Weather Bureau records from an average of the mean monthly temperatures for the entire period during which records are available. The departure of each season, therefore, affects the normal for the following season.

The general impression in regard to the exceptionally high temperature experienced during the winter of 1906–7 is confirmed by a comparison with the average records for a number of seasons. Temperature alone need be considered in making this comparison, although rainfall has an important direct effect upon temperature conditions. For the following comparison the records given by the United States Weather Bureau are used. As there is no report for Calvert the average of two points about equally distant on opposite sides of that place is used.

TABLE XXXIV.—*Mean monthly temperatures and departures from normal at Dallas, Calvert, and Victoria, Tex., November, 1906, to February, 1907.*

| Locality. | November. | | December. | | January. | | February. | |
|---|---|---|---|---|---|---|---|---|
| | Monthly mean. | Departure. | Monthly mean. | Departure. | Monthly mean. | Departure. | Monthly mean. | Departure. |
| | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. |
| Dallas | 54.3 | −0.6 | 51.6 | +3.8 | 53.4 | +8.5 | 51.2 | +6.6 |
| Calvert | 59.1 | + .1 | 56.8 | +4.1 | 59.8 | +9.6 | 54.8 | +2.8 |
| Victoria | 62.9 | −1.8 | 59.2 | +1.4 | 63.4 | +9.8 | 60.2 | +6.2 |

It will be noted that the departure from normal during November was very slight. The temperature conditions, therefore, during the usual period of entrance into hibernation were practically normal, the rise occurring during December and January, especially when weevils should normally have been in complete hibernation. Table XXXV continues the same study throughout the period of emergence from hibernation.

TABLE XXXV.—*Mean average temperatures and departures from normal at Dallas, Calvert, and Victoria, Tex., March to June, 1907.*

| Locality. | March. | | April. | | May. | | June. | |
|---|---|---|---|---|---|---|---|---|
| | Monthly mean. | Departure. | Monthly mean. | Departure. | Monthly mean. | Departure. | Monthly mean. | Departure. |
| | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. |
| Dallas | 66.7 | +11.1 | 61.4 | −4.2 | 65.8 | −7.7 | 78.8 | −1.9 |
| Calvert | 70.0 | + 9.2 | 62.2 | −5.9 | 66.6 | −7.3 | 76.6 | −4.4 |
| Victoria | 72.4 | + 9.7 | 69.4 | −3.3 | 73.0 | −5.0 | 81.6 | − .6 |

The unprecedented emergence during March is very easily explained by the remarkable temperature conditions during that month. In spite of the fact that emergence began earlier than had ever been known previously, it continued later also because of the exceptionally low temperatures prevailing during April, May, and June. A comparison of figures 1 and 2 with figures 6 to 8 is interesting and shows how strikingly the nature of the emergence movement may vary in respect to difference in climatic conditions. The careful examinations made to discover the termination of the emergence period were continued for fully two weeks after the last weevil was found. It seems impossible to explain the long-delayed emergence of some individuals. The lack of an explanation, however, does not alter the fact that emergence is probably not generally complete until after the middle of June.

TABLE XXXVI.—*General summary of experiments of 1906–7 on emergence from hibernation.*

| Locality. | Number of weevils— | | Number of weevils emerging | Percentage emerging. |
|---|---|---|---|---|
| | Put in cages. | Used as basis for percentage of emergence.[a] | | |
| Dallas, Tex. | 32,439 | 30,864 | 3,464 | 11.22 |
| Calvert, Tex. | 20,430 | 19,408 | 1,842 | 9.49 |
| Victoria, Tex. | 23,645 | 22,463 | [b]3,026 | 13.47 |
| Total and average | 76,514 | 72,735 | 8,332 | 11.45 |

[a] Basis for computing the percentage of emergence is 5 per cent less than the number of weevils put in cages owing to the escape of some weevils through the meshes of the wire.
[b] Two weevils not in summary.

A deduction of 5 per cent from the number of weevils placed in the hibernation experiments is made to furnish a more correct basis for determining percentages, on account of the fact that experiments have shown that about 5 per cent of a miscellaneous collection of weevils may be able to escape through 14-mesh wire (Pl. VII, fig. 1), such as was used in the construction of these cages. The percentage of survival is strikingly similar in each locality. The average surviving hibernation—approximately 11 per cent—is probably the highest that has ever occurred since the weevil entered Texas. Although observations have indicated that occasionally the percentage of survival may be as high as this in the field, it is fortunate for the cotton planter that such is very rarely the case.

## EFFECT OF TIME OF ENTERING HIBERNATION AND NATURE OF SHELTER UPON THE PERCENTAGE OF SURVIVAL.

One of the most important points upon which information was sought throughout these experiments was the effect of time of entering hibernation and nature of shelter upon the percentage of survival. The first confinement of weevils in the fall occurred fully a month earlier than the beginning of similar experiments the previous year, and it was expected that the intervals between their confinement in the cage and the time for successful hibernation might be sufficient to plainly reduce the proportion of weevils surviving.

TABLE XXXVII.—*Chronological arrangement of sectional records showing relative survival at Dallas, Calvert, and Victoria, Tex., 1906–7.*

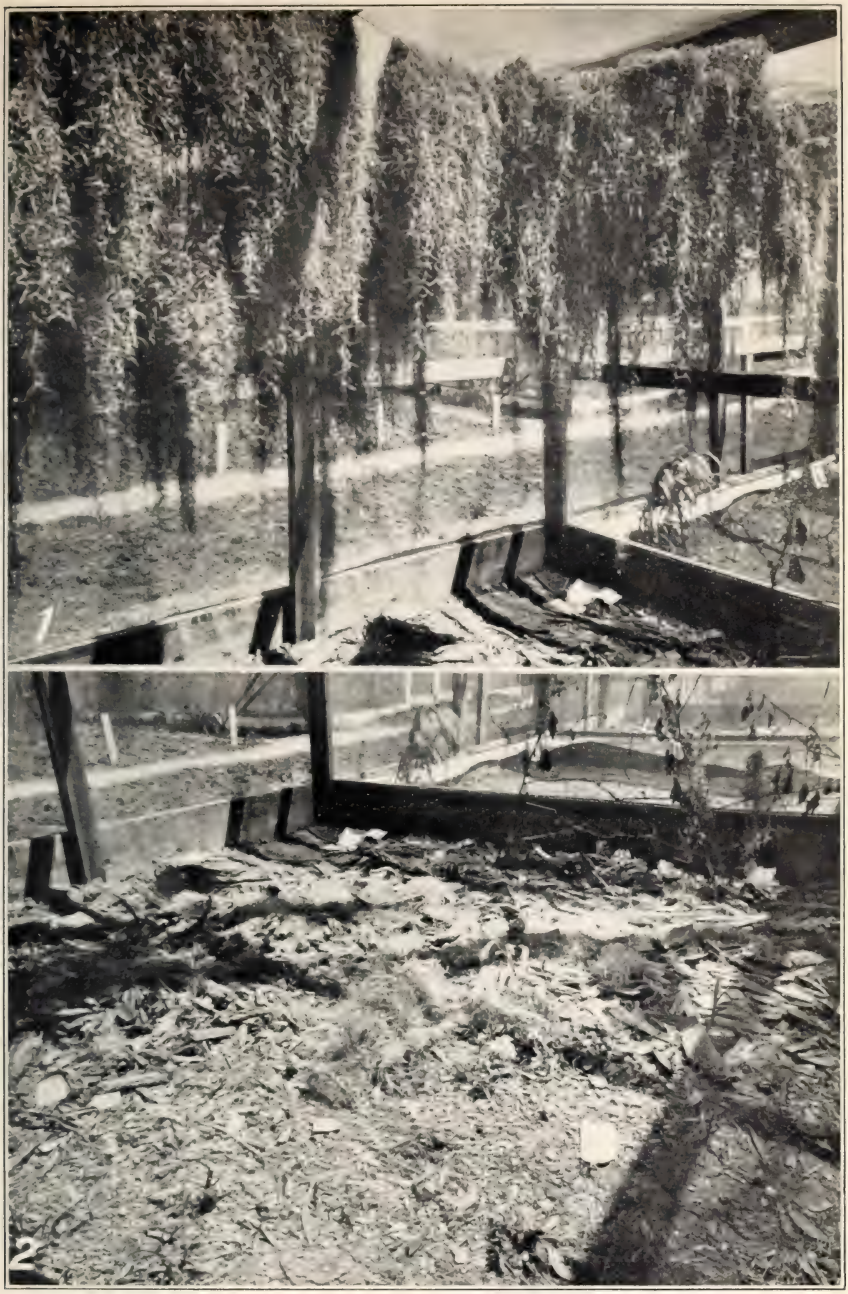
DALLAS.

| When started. | Section number. | Character of shelter and food. | Date of last emergence. | Basis number of weevils. | Total weevils emerged. | Percentage of survival. | Rank of section in survival. |
|---|---|---|---|---|---|---|---|
| 1906. | | | 1907. | | | | |
| Oct. 13 | 1 | Leaves and hay, 4 inches deep, cotton stalks left [a] | May 21 | 3,800 | 99 | 2.61 | 12 |
| Oct. 16 | 4 | Leaves and hay; stalks cut and left four days [b] | May 6 | 2,090 | 85 | 4.07 | 11 |
| Oct. 20 | 2 | Leaves and grass 4–5 inches deep; no food | May 19 | 3,610 | 226 | 6.26 | 7 |
| Oct. 24 | 7 | Spanish moss and chips; [c] cut food | June 17 | 3,325 | 231 | 6.95 | 6 |
| Oct. 30 | 8 | Leaves and grass 2–3 inches deep; no food [d] | June 15 | 2,850 | 250 | 8.85 | 5 |
| Nov. 5 | 5 | Leaves and grass 9–10 inches deep; stalks cut and left [e] | May 15 | 3,135 | 383 | 12.22 | 4 |
| Nov. 12 | 3 | Leaves and grass; no food [f] | May 21 | 3,040 | 448 | 14.74 | 3 |
| Nov. 13 | 9 | Leaves 8–10 inches deep; green cotton cut and left [g] | June 19 | 3,040 | 788 | 25.92 | 2 |
| Nov. 15 | 11 | Leaves 3–4 inches deep; stalks left standing | June 4 | 2,565 | 804 | 31.34 | 1 |
| Nov. 21 | 12 | ....do | June 8 | 1,570 | 65 | [h] 4.14 | 10 |
| Nov. 28 | 6 | Bare ground; no food | Apr. 29 | 975 | 46 | 4.72 | 8 |
| Dec. 6 | 10 | Bolls [i] on surface [j]<br>Bolls [i] buried [j] | May 2 | 864 | 39 | 4.51 | 9 |
| | | Total and average | | 30,864 | 3,464 | 11.22 | |

CALVERT.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Oct. 13 | 1 | Food, two days; grass and leaves 4–5 inches deep | June 12 | 2,375 | 75 | 3.15 | 7 |
| Oct. 19 | 4 | Grass and leaves 4–5 inches deep | May 30 | 2,375 | 116 | 4.88 | 5 |
| Oct. 25 | 7 | Spanish moss; chips | July 1 | 2,375 | 105 | 4.42 | 6 |
| Oct. 31 | 8 | Food two days; grass and leaves 4–5 inches deep | May 30 | 2,375 | 63 | 2.65 | 8 |
| Nov. 5 | 5 | Food dry; grass and leaves 4–5 inches deep | Apr. 26 | 2,375 | 45 | 1.89 | 9 |
| Nov. 12 | 9 | Food cut down, left dry; 10 inches grass and leaves | June 12 | 2,375 | 438 | 18.44 | 3 |
| Nov. 14 | 3 | Stalks cut down, left dry; 2 inches grass and leaves | May 31 | 2,375 | 253 | 10.65 | 4 |
| Nov. 25 | 6 | Field protection or bare; some grass | May 16 | 1,425 | 359 | 25.19 | 2 |
| Nov. 26 | 2 | No food; leaves and hay | June 12 | 1,358 | 380 | 27.98 | 1 |
| Dec. 3 | 10 | Bolls | Mar. 24 | (k) | 8 | ..... | 10 |
| | | Total and average | | 19,408 | 1,842 | 9.49 | |

[a] See Pl. VII, fig. 2.
[b] See Pl. VII, fig. 3.
[c] See Pl. VIII, figs. 1, 2.
[d] See Pl. IX, fig. 1.
[e] See Pl. IX, fig. 2.
[f] See Pl. IX, fig. 3.
[g] See Pl. X, fig. 2.
[h] The weevils put in on November 21 were brought from Brownsville, Tex. The low percentage of survival doubtless resulted from their weakened condition, owing to insufficient food during transportation.
[i] Bolls presumably infested.
[j] See Pl. X, fig. 1.
[k] No estimate made.




HANGING MOSS AS AFFECTING HIBERNATION AND EMERGENCE.

Fig. 1.—Section 7, with hanging moss in top of cage. Fig. 2.—Same section, ground conditions, started October 24, 1906; 6.95 per cent surviving; emergence ceased June 17, 1907. (Original.)

SHELTER CONDITIONS PRODUCING AVERAGE SURVIVAL AT DALLAS, TEX.

Fig. 1.—Section 8, started October 30, 1906; emergence ceased June 15, 1907; survival, 8.85 per cent. Fig. 2.—Section 5, started November 5, 1906; emergence ceased May 15, 1907; survival, 12.22 per cent. Fig. 3.—Section 3, started November 12, 1906; emergence ceased May 21, 1907; survival, 14.74 per cent. (Original.)

TABLE XXXVII.—*Chronological arrangement of sectional records showing relative survival at Dallas, Calvert, and Victoria, Tex., 1906–7*—Continued.

VICTORIA.

| When started. | Section number. | Character of shelter and food. | Date of last emergence. | Basis number of weevils. | Total weevils emerged. | Percentage of survival. | Rank of section in survival. |
|---|---|---|---|---|---|---|---|
| 1906. | | | 1907. | | | | |
| Oct. 25 | 1 | Weeds and grass 5 inches; stalks left. | May 11 | 2,375 | 201 | 8.46 | 7 |
| Do | 4 | Weeds and grass 5 inches; stalks removed | May 15 | 2,375 | 105 | 4.42 | 9 |
| Oct. 28 | 2 | Weeds and grass 4–5 inches; stalks cut, left | May 11 | 2,375 | 134 | 5.61 | 8 |
| Nov. 6 | 7 | Moss, bark, chips, etc.; no food | June 15 | 2,850 | 674 | 23.65 | 1 |
| Nov. 10 | 8 | Grass and weeds 5 inches; stalks removed | May 6 | 2,850 | 362 | 12.70 | 6 |
| Nov. 14 | 5 | Stalks pulled, left; grass and weeds 5 inches | Apr. 28 | 2,850 | 449 | 15.86 | 3 |
| Nov. 21 | 9 | Grass and weeds 10 inches; stalks pulled and left | May 23 | 2,850 | 374 | 13.19 | 4 |
| Do | 3 | Weeds and grass 2 inches; stalks pulled and left | do | 2,850 | 588 | 20.63 | 2 |
| Nov. 28 | 6 | Ground bare; no food | May 11 | 1,088 | 139 | 12.78 | 5 |
| Nov. 29 | 10 | Bolls[a] | Mar. 4 | (a) | 2 | | 10 |
| | | Total and average | | 22,463 | 3,028 | 13.47 | |

[a] Three bushels of bolls on the surface, and 3 bushels covered with 2 inches of earth.

The results of this work are exceptionally striking in the case of the Dallas record. The Calvert record ranges between that of Dallas and Victoria in regard to the clearness with which comparative effects are shown. In each case there is, however, a general tendency toward more successful hibernation as the season advances after the middle of October until the time when frosts occur. In the case of the Dallas records there occurred an almost uninterrupted increase in percentage of survival with each date upon which experiments were started. The apparent exceptions are readily explainable by other facts than the time of starting the experiment. Section 12, which ranged sixth, received weevils collected at Brownsville, Tex., which made it necessary to ship for a long distance. During this shipment their food supply became poor, and the weevils were undoubtedly much weaker upon being placed in the cage than were those which had been collected in the immediate vicinity of Dallas. Section 6 was not provided with any shelter for the weevils, and the percentage of survival was smaller on that account than in other sections started at about the same date. Section 10, which ranged ninth, received only infested bolls, upon and within which weevils were hibernating. From October 13 to November 15, under approximately similar conditions, the percentage of survival increased from 2.61 to 31.34. (See Pl. VII, figs. 2, 3.) A more forceful argument than this for the destruction of the food supply as early in the fall as is possible could hardly be given.

A combination of the records for those localities at which experiments were started upon the same or approximate dates, grouping them so that the chronological sequence is most clearly shown, adds additional emphasis to the statements which have just been made.

TABLE XXXVIII.—*Comparison of sectional records grouped by approximate initial dates.*

| Date. | Locality. | Section number. | Basis number of weevils. | Total number emerged. | Percentage of survival. | Rank in percentage of survival. |
|---|---|---|---|---|---|---|
| 1906. | | | | | | |
| Oct. 13 | Dallas | 1 | 3,800 | 99 | 2.61 | |
| Do | Calvert | 1 | 2,375 | 75 | 3.15 | 8 |
| Oct. 16 | Dallas | 4 | 2,090 | 85 | 4.07 | |
| | Total and average | | 8,265 | 259 | 3.13 | |
| Oct. 19 | Calvert | 4 | 2,375 | 116 | 4.88 | |
| Oct. 20 | Dallas | 2 | 3,610 | 226 | 6.26 | 7 |
| | Total and average | | 5,985 | 342 | 5.71 | |
| Oct. 24 | Dallas | 7 | 3,325 | 231 | 6.95 | |
| Oct. 25 | Calvert | 7 | 2,375 | 105 | 4.42 | |
| Do | Victoria | 1 | 2,375 | 201 | 8.46 | 5 |
| Do | do | 4 | 2,375 | 105 | 4.42 | |
| | Total and average | | 10,450 | 642 | 6.15 | |
| Oct. 28 | Victoria | 2 | 2,389 | 134 | 5.61 | |
| Oct. 30 | Dallas | 8 | 2,850 | 250 | 8.85 | 6 |
| Oct. 31 | Calvert | 8 | 2,375 | 63 | 2.65 | |
| | Total and average | | 7,614 | 447 | 5.87 | |
| Nov. 5 | Dallas | 5 | 3,135 | 383 | 12.22 | |
| Do | Calvert | 5 | 2,375 | 45 | 1.89 | 4 |
| Nov. 6 | Victoria | 7 | 2,850 | 674 | 23.65 | |
| | Total and average | | 8,360 | 1,102 | 13.18 | |
| Nov. 10 | Victoria | 8 | 2,850 | 362 | 12.70 | |
| Nov. 12 | Dallas | 3 | 3,040 | 448 | 14.74 | |
| Nov. 14 | Calvert | 9 | 2,375 | 438 | 18.44 | |
| Nov. 13 | Dallas | 9 | 3,040 | 788 | 25.92 | 2 |
| Nov. 14 | Victoria | 5 | 2,850 | 449 | 15.86 | |
| Nov. 15 | Dallas | 11 | 2,565 | 804 | 31.34 | |
| | Total and average | | 16,720 | 3,289 | 19.67 | |
| Nov. 21 | Dallas | 12 | 1,570 | 65 | [a] 4.14 | |
| Do | Victoria | 9 | 2,836 | 374 | 13.19 | 3 |
| Do | do | 3 | 2,850 | 588 | 20.63 | |
| | Total and average | | 7,256 | 1,027 | [b] 14.15 | |
| Nov. 25 | Calvert | 6 | 1,425 | 359 | 25.19 | |
| Nov. 26 | do | 2 | 1,358 | 380 | 27.98 | |
| Nov. 28 | Dallas | 6 | 975 | 46 | [c] 4.72 | 1 |
| Do | Victoria | 6 | 1,088 | 139 | [c] 12.78 | |
| | Total and average | | 4,846 | 924 | [d] 19.07 | |

[a] Brownsville, Tex., weevils.
[b] Average omitting Brownsville weevils, 16.91 per cent.
[c] Absolutely bare ground.
[d] Average without Dallas cage, 22.7 per cent.

In this table it may be seen that, taking all localities together, whenever experiments were started upon approximately the same date there is a most striking increase in successful survival at intervals between the middle of October and the middle of November. This table may be safely considered as representing in the most general way possible the facts in regard to this point. An interval of about eleven days between October 14 and 25 practically doubled the percentage of weevils surviving. Again, in an interval of about ten days between October 25 and November 5 the percentage was again

doubled, and an increase of 50 per cent was observable between November 5 and 14. After November 14 hibernation might have been successful for practically the maximum possible proportion of weevils. The relation of these figures may be most simply expressed in the following manner: Under similar conditions of shelter, but without a food supply, if the survival of weevils in Texas for October 15 is one, for October 25 it will be two; for November 5, four; and for November 15, six. These figures make it evident that from October 15 to November 15 constitutes the strategic period for attack upon the boll weevil. The attack can be made in two ways: (1) By the destruction or removal of the conditions favorable for the shelter of the weevil through the winter; (2) by the destruction of the food supply. These conclusions have frequently been stated and are here repeated because the facts here presented prove more conclusively than have any other data heretofore obtained the unquestionable importance of fall work in combating the boll weevil. The benefit, obviously, will always be realized during the following season by a much smaller injury to the crop. Considerations, both of minimum expense and of maximum effectiveness, emphasize this conclusion.

### SURVIVAL OF WEEVILS BY LOCALITIES AND CAGE SECTIONS.

In practically all of the sections it may be considered that the emergence period began during the last few days of February and the first few days of March, March 1 being, approximately, the average date in each case. In the following table the summaries of the sectional records in each locality are given, together with the data necessary to show the maximum length of the hibernation period and the percentage of survival in each section:

TABLE XXXIX.—*Maximum hibernation period and percentage of survival by sections, 1906.*

DALLAS.

| Section number. | When installed. | Weevils started. | Number used as basis of percentage. | Date of last emergence. | Total weevils emerged. | Percentage of survival. |
|---|---|---|---|---|---|---|
| | 1906. | | | 1907. | | |
| 1 | Oct. 13 | 4,000 | 3,800 | May 21 | 99 | 2.61 |
| 2 | Oct. 20 | 3,800 | 3,610 | May 19 | 226 | 6.26 |
| 3 | Nov. 12 | 3,200 | 3,040 | May 21 | 448 | 14.74 |
| 4 | Oct. 16 | 2,200 | 2,090 | May 6 | 85 | 4.07 |
| 5 | Nov. 5 | 3,300 | 3,135 | May 15 | 383 | 12.22 |
| 6 | Nov. 28 | 1,025 | 975 | Apr. 29 | 46 | 4.72 |
| 7 | Oct. 24 | 3,500 | 3,325 | June 17 | 231 | 6.95 |
| 8 | Oct. 30 | 3,000 | 2,850 | June 15 | 250 | 8.85 |
| 9 | Nov. 13 | 3,200 | 3,040 | June 19 | 788 | 25.92 |
| 10 | Dec. 6 | 864 | 864 | May 2 | 39 | 4.51 |
| 11 | Nov. 15 | 2,700 | 2,565 | June 4 | 804 | 31.34 |
| 12 | Nov. 21 | 1,650 | 1,570 | June 8 | 65 | 4.14 |
| Total and average | | 32,439 | 30,864 | | 3,464 | 11.22 |

TABLE XXXIX.—*Maximum hibernation period and percentage of survival by sections, 1906*—Continued.

CALVERT.

| Section number. | When installed. | Weevils started. | Number used as basis of percentage. | Date of last emergence. | Total weevils emerged. | Percentage of survival. |
|---|---|---|---|---|---|---|
| | 1906. | | | 1907. | | |
| 1 | Oct. 13 | 2,500 | 2,375 | June 12 | 75 | 3.15 |
| 2 | Nov. 26 | 1,430 | 1,358 | ....do.... | 380 | 27.98 |
| 3 | Nov. 14 | 2,500 | 2,375 | May 31 | 253 | 10.65 |
| 4 | Oct. 19 | 2,500 | 2,375 | May 30 | 116 | 4.88 |
| 5 | Nov. 5 | 2,500 | 2,375 | Apr. 26 | 45 | 1.89 |
| 6 | Nov. 25 | 1,500 | 1,425 | May 16 | 359 | 25.19 |
| 7 | Oct. 25 | 2,500 | 2,375 | July 1 | 105 | 4.42 |
| 8 | Oct. 31 | 2,500 | 2,375 | May 30 | 63 | 2.65 |
| 9 | Nov. 12 | 2,500 | 2,375 | June 12 | 438 | 18.44 |
| 10 | Dec. 3 | Bolls. | (a) | Mar. 24 | 8 | ..... |
| Total and average | ..... | 20,430 | 19,408 | ..... | 1,842 | 9.49 |

VICTORIA.

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | Oct 25 | 2,500 | 2,375 | May 11 | 201 | 8.46 |
| 2 | Oct. 28 | 2,515 | 2,389 | ....do.... | 134 | 5.61 |
| 3 | Nov. 21 | 3,000 | 2,850 | May 23 | 588 | 20.63 |
| 4 | Oct. 25 | 2,500 | 2,375 | May 15 | 105 | 4.42 |
| 5 | Nov. 14 | 3,000 | 2,850 | Apr. 28 | 449 | 15.86 |
| 6 | Nov. 28 | 1,145 | 1,088 | May 11 | 139 | 12.78 |
| 7 | Nov. 6 | 3,000 | 2,850 | June 15 | 674 | 23.65 |
| 8 | Nov. 10 | 3,000 | 2,850 | May 6 | 362 | 12.70 |
| 9 | Nov. 21 | 2,985 | 2,836 | May 23 | 374 | 13.19 |
| 10 | Nov. 29 | (b) | (b) | Mar. 4 | 2 | ..... |
| Total and average | ..... | 23,645 | 22,463 | ..... | 3,028 | 13.47 |

a No estimate made. b Three bushels of bolls on surface and 3 bushels covered with earth.

The longest period of hibernation occurred at Calvert among the weevils placed in section 7 on October 25, the last weevil emerging from this section being taken on July 1, 1907. During this period of over eight months this weevil survived without a particle of food. This may be considered as representing the maximum hibernation period, and in the case of an insect producing numerous generations during each season it is surprising that the hibernation period can be so greatly prolonged.

The largest average percentage of survival occurred at Victoria, although the variation between the three localities was not unexpectedly great. The nature of the shelter provided in each section has been indicated upon page 57. A comparison of the records for section 7 for Calvert and Dallas with those for the same section at Victoria shows that at the last-named place the survival was four times as great as in the average of Dallas and Calvert. The shelter provided was as closely similar in the case of this section as in any of the series, and the significant point of difference appears, therefore, to be the time when weevils were inclosed. At Dallas and Calvert this occurred on October 24 and 25, respectively, while at Victoria weevils were not placed in the cage until November 6. Apparently, therefore, the much larger survival at Victoria was due

primarily to the starting of the experiment about twelve days later than in the other two localities.

The significance of the time of beginning the experiments is well emphasized by the records for sections 2 and 6 at Calvert. These two sections furnished by far the highest percentages of survival at that place, and apparently the only fact explaining this is that the experiment was started in each case at the time which was most favorable for successful hibernation, i. e., about November 25. This date was ten or twelve days later than those for sections 3 and 9, which present the next higher percentages of survival. An average of these two sections shows that among the weevils starting hibernation about November 12, 14.5 per cent survived, while among those starting hibernation about November 25, about 26.5 per cent survived.

The records for Dallas show that the three highest percentages of survival occurred in sections 11, 9, and 3, which were started between November 12 and 15.

In each locality the average date for the termination of emergence occurred between May 22 and 29. It is evident, therefore, that during 1906 the period of emergence from hibernation covered practically three months for an average of all of the sections and slightly more than four months for the last emerged weevils.

### MONTHLY SUMMARY OF EMERGENCE RECORDS.

While it is important to know, approximately at least, the maximum limit of the emergence period, it may seem more desirable to determine the time at which a majority of weevils surviving had emerged. It is more convenient in using the records to compare them in four-week periods rather than according to calendar months.

TABLE XL.—*Emergence in 1907, by four-week periods.*

| Locality. | Mar. 1–28, weevils emerged. | | Mar. 29–Apr. 25, weevils emerged. | | Apr. 26–May 23, weevils emerged. | | May 24–July 1, weevils emerged. | | Total emergence. |
|---|---|---|---|---|---|---|---|---|---|
| | Number. | Per cent of total. | Number. | Per cent of total. | Number. | Per cent of total. | Number. | Per cent of total. | |
| Dallas | 2,486 | 71.8 | 484 | 14.0 | 452 | 13.0 | 42 | 1.2 | 3,464 |
| Calvert | 1,053 | 57.1 | 410 | 22.3 | 284 | 15.4 | 95 | 5.2 | 1,842 |
| Victoria | 2,399 | 79.3 | 476 | 15.7 | 119 | 3.9 | 32 | 1.1 | 3,026 |
| Total and average | 5,938 | 71.3 | 1,370 | 16.4 | 855 | 10.3 | 169 | 2.0 | 8,332 |

### WEEKLY EMERGENCE RECORDS.

The following table presents a summary of the daily emergence records for each section during seven-day periods from March 1 to the end of the hibernation period. These records are particularly inter-

esting in showing the variation occurring in emergence in the same section and locality during the different periods.

TABLE XLI.—*Summary of emergence of weevils in cage sections by weekly periods, March 1 to June 20, 1907.*

DALLAS.

| Weekly period. | Number of weevils emerged in section number— | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. |
| Mar. 1–7 | 40 | 69 | 155 | 36 | 151 | 21 | 73 | 79 | 212 | 12 | ..... | ..... |
| Mar. 8–14 | 8 | 36 | 51 | 10 | 46 | 7 | 25 | 31 | 120 | 7 | 65 | 7 |
| Mar. 15–21 | 17 | 39 | 85 | 11 | 89 | 11 | 64 | 35 | 202 | 13 | 145 | 10 |
| Mar. 22–28 | 10 | 21 | 38 | 8 | 51 | 2 | 25 | 22 | 123 | 4 | 189 | 11 |
| Mar. 29–Apr. 4 | 4 | 20 | 19 | 3 | 8 | 1 | 4 | 15 | 7 | 1 | 49 | 4 |
| Apr. 5–11 | 7 | 13 | 30 | 7 | 10 | 3 | 7 | 10 | 17 | 1 | 78 | 11 |
| Apr. 12–18 | 1 | 6 | 12 | 1 | 7 | 0 | 8 | 5 | 10 | 0 | 55 | 6 |
| Apr. 19–25 | 1 | 5 | 8 | 0 | 1 | 0 | 2 | 3 | 6 | 0 | 15 | 0 |
| Apr. 26–May 2 | 5 | 10 | 16 | 3 | 5 | 1 | 2 | 20 | 8 | 1 | 27 | 1 |
| May 3–9 | 2 | 3 | 21 | 3 | 7 | 0 | 7 | 14 | 26 | 0 | 40 | 6 |
| May 10–16 | 2 | 2 | 10 | 0 | 8 | 0 | 2 | 7 | 29 | 0 | 58 | 3 |
| May 17–23 | 2 | 2 | 3 | 0 | 0 | 0 | 8 | 3 | 16 | 0 | 67 | 2 |
| May 24–30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 4 | 0 | 12 | 1 |
| May 31–June 6 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 4 | 0 | 4 | 2 |
| June 7–13 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 0 | 0 | 1 |
| June 14–20 | ..... | ..... | ..... | ..... | ..... | ..... | 2 | 1 | 1 | ..... | ..... | ..... |
| Total | 99 | 226 | 448 | 82 | 383 | 46 | 231 | 250 | 788 | 39 | 804 | 65 |

CALVERT.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mar. 4–7 | 25 | 99 | 54 | 23 | 15 | 136 | 9 | 7 | 49 | 3 | ..... | ..... |
| Mar. 8–14 | 9 | 39 | 23 | 10 | 6 | 47 | 4 | 2 | 27 | 1 | ..... | ..... |
| Mar. 15–21 | 9 | 54 | 37 | 12 | 9 | 45 | 2 | 3 | 55 | 2 | ..... | ..... |
| Mar. 22–28 | 7 | 41 | 36 | 22 | 6 | 57 | 5 | 11 | 50 | 2 | ..... | ..... |
| Mar. 29–Apr. 4 | 2 | 23 | 18 | 4 | 4 | 22 | 3 | 5 | 47 | 0 | ..... | ..... |
| Apr. 5–11 | 0 | 14 | 9 | 7 | 3 | 21 | 6 | 11 | 44 | 0 | ..... | ..... |
| Apr. 12–18 | 8 | 28 | 24 | 9 | 1 | 16 | 6 | 3 | 39 | 0 | ..... | ..... |
| Apr. 19–25 | 2 | 6 | 2 | 1 | 0 | 6 | 1 | 2 | 13 | 0 | ..... | ..... |
| Apr. 26–May 2 | 2 | 9 | 9 | 6 | 1 | 3 | 5 | 2 | 21 | 0 | ..... | ..... |
| May 3–9 | 3 | 24 | 23 | 16 | 0 | 3 | 5 | 7 | 32 | 0 | ..... | ..... |
| May 10–16 | 1 | 12 | 9 | 2 | 0 | 3 | 4 | 4 | 24 | 0 | ..... | ..... |
| May 17–23 | 5 | 17 | 6 | 2 | 0 | 0 | 8 | 3 | 13 | 0 | ..... | ..... |
| May 24–30 | 1 | 8 | 2 | 2 | 0 | 0 | 16 | 3 | 12 | 0 | ..... | ..... |
| May 31–June 6 | 0 | 3 | 1 | 0 | 0 | 0 | 16 | 0 | 10 | 0 | ..... | ..... |
| June 7–13 | 1 | 3 | 0 | 0 | 0 | 0 | 4 | 0 | 2 | 0 | ..... | ..... |
| June 14–20 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | ..... | ..... |
| June 21–27 | ..... | ..... | ..... | ..... | ..... | ..... | 5 | ..... | ..... | ..... | ..... | ..... |
| June 28–July 4 | ..... | ..... | ..... | ..... | ..... | ..... | 1 | ..... | ..... | ..... | ..... | ..... |
| Total | 75 | 380 | 253 | 116 | 45 | 359 | 105 | 63 | 438 | 8 | ..... | ..... |

VICTORIA.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Feb. 28 | 39 | 24 | 69 | 13 | 60 | 35 | 29 | 31 | 63 | ..... | ..... | ..... |
| Mar. 1–7 | 32 | 23 | 95 | 26 | 80 | 29 | 36 | 92 | 72 | 2 | ..... | ..... |
| Mar. 8–14 | 54 | 36 | 130 | 22 | 103 | 24 | 63 | 107 | 76 | 0 | ..... | ..... |
| Mar. 15–21 | 36 | 18 | 94 | 19 | 88 | 25 | 124 | 72 | 67 | 0 | ..... | ..... |
| Mar. 22–28 | 18 | 10 | 54 | 13 | 58 | 18 | 170 | 26 | 30 | 0 | ..... | ..... |
| Mar. 29–Apr. 4 | 9 | 6 | 51 | 9 | 17 | 5 | 19 | 15 | 16 | 0 | ..... | ..... |
| Apr. 5–11 | 3 | 8 | 44 | 0 | 26 | 0 | 64 | 8 | 12 | 0 | ..... | ..... |
| Apr. 12–18 | 5 | 5 | 28 | 5 | 7 | 0 | 47 | 5 | 25 | 0 | ..... | ..... |
| Apr. 19–25 | 1 | 1 | 9 | 1 | 6 | 0 | 11 | 2 | 6 | 0 | ..... | ..... |
| Apr. 26–May 2 | 1 | 0 | 4 | 1 | 4 | 0 | 14 | 1 | 1 | 0 | ..... | ..... |
| May 3–9 | 2 | 2 | 8 | 0 | 0 | 0 | 31 | 3 | 4 | 0 | ..... | ..... |
| May 10–16 | 1 | 1 | 1 | 2 | 0 | 1 | 20 | 0 | 0 | 0 | ..... | ..... |
| May 17–23 | 0 | 0 | 1 | 0 | 0 | 0 | 14 | 0 | 2 | 0 | ..... | ..... |
| May 24–30 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | ..... | ..... |
| May 31–June 6 | 0 | 0 | 0 | 0 | 0 | 0 | 21 | 0 | 0 | 0 | ..... | ..... |
| June 7–13 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | ..... | ..... |
| June 14–20 | ..... | ..... | ..... | ..... | ..... | ..... | 1 | ..... | ..... | ..... | ..... | ..... |
| Total | 201 | 134 | 588 | 105 | 449 | 137 | 674 | 362 | 374 | 2 | ..... | ..... |

There is no indication that the time at which an experiment was begun affected essentially the nature of the emergence movement. The nature of the shelter, however, does seem to have an important influence. This is most clearly marked in section 7, where the experimental shelter was Spanish moss. At Victoria after about the 12th of April more weevils emerged from this section than from all others combined. This effect was less marked in the other localities, but in each case there appeared to be a considerable delay in emergence, due to the nature of this shelter. Owing to the fact that this moss is living and growing while hanging in the cages or on the trees, it takes up moisture as no other class of shelter does. The evaporation of this moisture during the daytime then serves to keep the mass of moss cool, and it is a well-known fact that the temperature in bunches of this moss is several degrees lower than that of the air during the daytime. Undoubtedly the lower temperature in the moss is the factor which retards the emergence of the weevils so decidedly. This factor may also be considered responsible for the smaller activity of weevils shown in the moss sections during the winter. (See Table XXXI, p. 63.)

A somewhat more detailed statement of the emergence shows more plainly the peculiar manner in which this was distributed during 1907. The figures are arranged for seven-day periods, and show the average temperature conditions prevailing as well as the percentage total of emergence occurring during each week.

TABLE XLII.—*Weekly summary of emergence records, showing relation to effective temperatures, 1907.*

| Date. | Locality. | Mean average effective temperature. | Number of weevils emerged. | Percentage of total emergence. |
|---|---|---|---|---|
| 1907. | | °F. | | |
| Mar. 1–7 | Calvert | 30.0 | 420 | 22.8 |
| | Dallas | 19.7 | 848 | 24.5 |
| | Victoria | 24.7 | [a]363 | [a]12.0 |
| | | | 481 | 15.9 |
| Mar. 8–14 | Calvert | 25.7 | 168 | 9.1 |
| | Dallas | 21.0 | 413 | 11.9 |
| | Victoria | 30.5 | 609 | 20.3 |
| Mar. 15–21 | Calvert | 30.5 | 228 | 12.4 |
| | Dallas | 27.0 | 721 | 20.8 |
| | Victoria | 29.0 | 549 | 18.0 |
| Mar. 22–28 | Calvert | 36.6 | 237 | 12.9 |
| | Dallas | 33.0 | 504 | 14.6 |
| | Victoria | 32.5 | 397 | 13.1 |
| Mar. 29–Apr. 4 | Calvert | 23.0 | 128 | 7.0 |
| | Dallas | 17.5 | 135 | 4.0 |
| | Victoria | 22.8 | 147 | 4.8 |
| Apr. 5–11 | Calvert | 28.8 | 115 | 6.2 |
| | Dallas | 24.0 | 194 | 5.6 |
| | Victoria | 31.9 | 165 | 5.4 |
| Apr. 12–18 | Calvert | 24.9 | 134 | 7.3 |
| | Dallas | 20.0 | 111 | 3.2 |
| | Victoria | 28.7 | 127 | 4.2 |
| Apr. 19–25 | Calvert | 17.8 | 33 | 1.8 |
| | Dallas | 13.0 | 44 | 1.3 |
| | Victoria | 19.0 | 37 | 1.2 |
| Apr. 26–May 2 | Calvert | 24.8 | 58 | 3.1 |
| | Dallas | 16.3 | 99 | 2.9 |
| | Victoria | 26.3 | 26 | .86 |

[a] On February 28.

TABLE XLII.—*Weekly summary of emergence records, showing relation to effective temperatures, 1907*—Continued.

| Date. | Locality. | Mean average effective temperature. | Number of weevils emerged. | Percentage of total emergence. |
|---|---|---|---|---|
| 1907. | | °F. | | |
| May 3–9 | Calvert | 26.4 | 113 | 6.1 |
| | Dallas | 20.2 | 129 | 3.7 |
| | Victoria | 29.3 | 50 | 1.6 |
| May 10–16 | Calvert | 31.9 | 59 | 3.2 |
| | Dallas | 24.0 | 121 | 3.5 |
| | Victoria | 32.5 | 26 | .86 |
| May 17–23 | Calvert | 35.5 | 54 | 3.0 |
| | Dallas | 31.2 | 103 | 3.0 |
| | Victoria | 31.8 | 17 | .56 |
| May 24–30 | Calvert | 33.0 | 49 | 2.6 |
| | Dallas | 23.3 | 20 | .6 |
| | Victoria | 33.4 | 8 | .26 |
| May 31–June 6 | Calvert | 30.7 | 30 | 1.6 |
| | Dallas | 38.0 | 13 | .4 |
| | Victoria | 30.9 | 21 | .7 |
| June 7–13 | Calvert | 43.2 | 10 | .5 |
| | Dallas | 38.0 | 5 | .15 |
| | Victoria | 40.0 | 2 | .07 |
| June 14–20 | Calvert | 37.4 | 5 | .3 |
| | Dallas | 36.0 | 4 | .12 |
| | Victoria | 36.8 | 1 | .03 |
| June 21–27 | Calvert | 39.4 | 1 | .01 |
| | Dallas | | | |
| | Victoria | | | |

Total emergence:

| | |
|---|---|
| Calvert | 1,842 |
| Dallas | 3,464 |
| Victoria | 3,026 |
| Grand total | 8,332 |

The large percentage of total emergence occurring during the first week of March is very striking and unquestionably also very exceptional. Only the extremely high range in temperature can explain this unusual record. Taking the average of the three locations, practically one-fourth of the total emergence occurred during the first week of March. During the following two weeks more than another one-fourth also emerged. During this period the temperatures averaged as high as they do ordinarily in May; and owing to the fact that a considerable majority of weevils had left shelter before the end of March the number emerging after that time shows a marked decrease.

It must not be supposed that these statements represent anything like usual conditions, although they unquestionably represent the facts in regard to emergence in 1907. The comparison of these records with those for Dallas and Keatchie (see p. 44) in 1906 will show clearly the exceptional nature of the variation.

It should be stated that when the emergence takes place as rapidly as was the case in March, 1907, the actual number of living weevils in the field may be expected to increase for some time because of the fact that a larger number of weevils is added to the total living on account of continued emergence than is lost on account of death among weevils which have previously emerged.

## LONGEVITY OF WEEVILS AFTER EMERGENCE FROM HIBERNATION.

Preceding records have shown that on the average the weevils surviving hibernation had lived for over five months before their emergence. It is impossible to determine even approximately how old weevils may have been at the time they were placed in the hibernation cages. The longevity records here shown must, therefore, be very conservative. They may indicate very closely the average length of life of weevils which survive hibernation, but should not be considered as showing actually the maximum longevity. It has seemed advisable, therefore, to base the studies upon longevity after emergence from hibernation, since the exact dates for emergence and for deaths have been carefully determined.

As the weevils were collected daily from the cages, those found at each date must have emerged practically upon that date. It was the general practice to divide the weevils from each section of the cage into two lots of approximately equal numbers, one lot being placed in a series in which they received no food and the second lot being placed in a series which was supplied whatever stage of cotton was then available to weevils in the field where the experiments were being made. Thus, early in the season at Dallas, all weevils were necessarily placed in unfed series, since no cotton existed in the field. In each locality the first food consisted of the tender leaves of volunteer or sprout plants. As soon as squares were formed in the field these were supplied to the weevils in the fed series of experiments.

As a general rule the weevils emerging upon three consecutive days were placed in a cage bearing the same series designation, and the average date of emergence was considered as applying to the entire lot. This arrangement was necessary to reduce the amount of work required in caring for so many cages as would be needed to keep each day's weevils entirely separate.

In both the fed and unfed series frequent examinations were made to determine the time of death of each weevil, and fresh food was supplied to weevils in the fed series. Upon the death of a weevil its sex was determined and its period of life after emergence was also recorded. The manner in which sex can be positively determined is described in succeeding paragraphs. (See p. 91.) In this way the records for each lot bearing a serial number were kept by themselves and the results for each series are comparable with all others. While it would be most significant to present the records in the form of a summary of each series which would allow these comparisons to be seen, the necessity for abridging the tabular matter, so far as may be possible, prevents our doing so. Therefore for both the "unfed" and for the "fed" experiments we can give only the grand totals and averages with general statements based upon the tabular studies from which these figures are obtained.

LONGEVITY OF UNFED WEEVILS AFTER EMERGENCE FROM HIBERNATION.

Since the duration of life of unfed weevils was so much shorter than for fed weevils, the records of the former will be considered first. The principal object in the experiments with unfed weevils was to determine the time which they might survive while waiting for the growth of a food supply in the spring. The results have a most important special bearing upon the advisability of hastening or deferring the time of planting of cotton, especially when considered in connection with the period of emergence from hibernation. The figures given are based upon completed records only, all partial records having been discarded.

TABLE XLIII.—*Longevity of unfed weevils after emergence from hibernation, March to July, 1907.*

| Locality. | Number of series tested unfed. | Total weevils emerged. | Weevils in series lots. | | | Maximum life. | | Average duration of life. | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total. | ♂ | ♀ | ♂ | ♀ | ♂ | ♀ | Both sexes. |
| Texas: | | | | | | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* |
| Calvert | 25 | 1,085 | 1,079 | 585 | 494 | 48 | 26 | 8.05 | 8.09 | 8.07 |
| Dallas | 19 | 2,317 | 2,179 | 1,178 | 1,009 | 90 | 88 | 13.00 | 11.09 | 12.50 |
| Victoria | 17 | 1,418 | 1,360 | 875 | 485 | 44 | 40 | 8.00 | 7.40 | 8.20 |
| Total and average | 61 | 4,820 | 4,618 | 2,638 | 1,988 | 90 | 88 | 10.30 | 9.80 | 10.10 |

The records both for maximum and average duration of life are very important. In the record showing maximum and average duration of life for each sex in each locality the time at Dallas exceeds by 50 per cent the time at either Calvert or Victoria. It should be stated that when weevils are kept in confinement it is probable that the most favorable conditions which can be furnished them can hardly be supposed to prolong their life beyond the normal condition in the field. Any unfavorable conditions in the cages will shorten the period. It was found in the course of the work that whenever sunshine was allowed to strike directly on the lantern globe breeding jars in which the weevils were for the most part confined, the heat and excessive humidity generated within the globe caused an abnormal activity among the weevils, and if prolonged or frequently repeated, it resulted in their early death. It was also found that in the breeding cages among the unfed weevils the degree of moisture was less than would normally occur on plants or at the surface of the ground in the field. This dryness also naturally shortens the life of weevils. In an experiment at Dallas series 14 was kept with plenty of moisture while series 15 was dry. Otherwise conditions in the two series were identical. The average life in the wet series was 20.3 days while in the dry series it was but 7.1 days. Other experiments pointed to the same conclusion.

These facts indicate that the records for Calvert and Victoria are probably considerably below the normal survival period for emerged weevils in the field, and the records for Dallas are at least conservative. The difference in duration of life between the males and females was but slight, but rather uniformly in favor of the males. In each locality the maximum longevity was shown by males. This fact agrees with previous conclusions regarding the relative duration of life of the two sexes. Apparently copulation does not materially affect the longevity of either sex. In this connection it may be stated that unquestionable instances of mating were found among weevils immediately after their emergence and before there was any possibility of their having fed. This was of rare occurrence, and the question of fertility resulting was not positively determined.

From the records it becomes evident that many emerged weevils may survive from six to twelve weeks without food and that the average survival for all weevils may be between one and two weeks.

There is some evidence to show that it is possible for these unfed weevils to move rather extensively in search of food, and undoubtedly this is done in many instances. Other observations, however, indicate that if food is not found in the vicinity of emergence the weevils may become quiet for a considerable period before again seeking food, and in this way their movement may occur only through comparatively short distances. It is also probable that when they first find a food supply they do not intentionally leave it in search of other plants which may be in a more advanced stage of growth.

As to the proportion of each sex among the weevils surviving in these experiments it appears that 57 per cent were males. The maximum longevity of any weevil was ninety days. This was a male which was kept under outdoor conditions from March 1, when it emerged, to May 30, when it died. The maximum life for a female was eighty-eight days. This weevil emerged April 25 and died July 20. The average temperature under which this lot of weevils was kept ranged between 45 and 60 degrees and the average length of life for all of the 55 weevils tested in series 17 at Dallas was slightly more than thirty days. This emphasized the important effect of temperature upon the period of survival without food.

The grand total for average duration of life shows 10.1 days for more than 4,600 weevils. The males lived on an average one-half day longer than did the females.

It would be both interesting and valuable if the records showing a summary of the results for each sex in each series of experiments could be presented in full. It is thought, however, that the corresponding records for the fed weevils have a greater value and it may be allowable to present in place of the full records for the unfed weevils merely a brief statement of the most important facts as to the survival of each sex.

The most apparent fact is that there is a consistent increase in duration of life without food in both sexes in a northern locality, as at Dallas, as compared with a southern locality, as at Victoria, while Calvert occupies an intermediate position both in the starvation period and geographically. Lower temperatures are obviously directly correlated to the degree of activity of the insects and thus determine directly the limit of endurance without food. But in no case is there any very marked variation between the sexes in the same locality.

It appears that practically two-thirds of all weevils died during the first ten days after their emergence. One-fourth of the total number tested lived to between eleven and twenty days. Beyond twenty days the percentage surviving becomes comparatively small, and between fifty and ninety days the percentage for each ten-day period is rather surprisingly uniform. It is very evident, however, that even in a season when the bulk of emergence may occur as unusually early as it did in 1907 it would be absolutely impossible to exterminate the weevil by any possible delay in the time of planting cotton.

### LONGEVITY OF FED WEEVILS AFTER EMERGENCE FROM HIBERNATION.

The records indicating the longevity of weevils which were fed after their emergence from hibernation have been prepared in a similar way to show results comparable with those for unfed weevils which have just been given. They form the second part of the comparative series of experiments to determine longevity. The conditions of food supply, while kept as favorable as was possible, could not at best equal the natural conditions in the field, although the weevils were evidently saved the trouble which they might have experienced in the field of finding their first food supply. The considerations which have previously been mentioned in regard to the effect of high temperature and excessive moisture in the jars when exposed to sunshine apply with fully as much force to the fed as to the unfed series of experiments.

TABLE XLIV.—*Longevity of weevils fed after emergence from hibernation, March to September, 1907.*

| Locality. | Number of series tested, fed. | Total weevils emerged. | Number of weevils in series. | | | Maximum life. | | Average duration of life. | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total. | ♂ | ♀ | ♂ | ♀ | ♂ | ♀ | Both sexes. |
| Texas: | | | | | | | | | | |
| Dallas | 7 | 998 | 901 | 490 | 411 | 130 | 108 | 38.4 | 38.0 | 38.2 |
| Calvert | 26 | 740 | 715 | 363 | 352 | 92 | 118 | 29.2 | 30.7 | 30.0 |
| Victoria | 20 | 1,450 | 1,349 | 785 | 564 | 84 | 86 | 15.1 | 14.2 | 14.7 |
| Total and average | 53 | 3,188 | 2,965 | 1,638 | 1,327 | 130 | 118 | 25.2 | 25.9 | 25.5 |

Only about two-thirds as many weevils were carried through in the fed tests as in the unfed tests. Among the total of 2,965 weevils 55 per cent were males, while in the unfed experiments 57 per cent were males. The average duration of life shows but very slight variation between the sexes, both living between twenty-five and twenty-six days. This average is somewhat smaller than has previously been obtained in similar experiments, and this is probably due to the greater exposure to sunshine of the cages in which the weevils were kept in this series of experiments. The average period of life with food was about two and one-half times that without food.

Among the fed weevils, as among the unfed, the longest life occurred at Dallas. This also was a male weevil which emerged from hibernation on May 6 and survived until September 13, or one hundred and thirty days. The greatest length of life for a female occurred at Calvert. This weevil emerged on April 11 and died on August 7, having been active one hundred and eighteen days.

The full length of life of the last weevil dying in these experiments is also a matter of interest. This weevil was collected in the field at Dallas and placed in the hibernation cage on October 16, 1906. From that time until May 6, 1907, it had no food. The period from its collection until its death lacked but a day or two of being eleven months, during three-fifths of which period it existed without food. This is next to the longest lived boll weevil of which we have record, the longer record being slightly more than eleven months in the case of a male weevil hibernated at Victoria in 1903.

In a study of the emergence movement and of the duration of life of fed weevils by ten-day periods we have used the total number of weevils of each sex observed in each locality as the basis upon which we have determined the percentage of mortality occurring in each successive ten-day period. The full records for each locality have been omitted and only the totals for each sex in each locality have been included in Table XLV (p.88). The emergence from hibernation was distributed through four months, or slightly more, in 1907. A study of the omitted records shows that, as a rule, the weevils living longest emerged at approximately the middle of the emergence movement. It is probable that these weevils were among those which entered hibernation at the most favorable period during the preceding fall and that they found also the most favorable class of shelter conditions to protect them during the winter. The importance of breaking up this succession of conditions, so favorable to the survival of weevils, their maximum length of life, and, consequently, their greatest injuriousness, need only be mentioned to be appreciated. That early fall destruction of stalks, the cleaning up of rubbish which might shelter weevils most favorably during the winter, and the early planting and uniform planting of the crop are all logical parts or steps

in the rational method of fighting the boll weevil is plainly shown by these studies.

TABLE XLV.—*Comparison of summaries for longevity of fed weevils, by ten-day periods, in each locality.*

MALE WEEVILS.

| Locality. | Number of weevils in series. | Weevils dying within a period of— | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1–10 days. | | 11–20 days. | | 21–30 days. | | 31–40 days. | | 41–50 days. | | 51–60 days. | |
| | | Number. | Per cent. | Number. | Per cent. | Number. | Per cent. | Number. | Per cent. | Number. | Per cent. | Number. | Per cent. |
| Dallas | 490 | 47 | 9.6 | 72 | 14.7 | 87 | 17.7 | 68 | 13.9 | 87 | 17.7 | 47 | 9.6 |
| Calvert | 363 | 86 | 23.8 | 61 | 16.9 | 60 | 16.7 | 50 | 13.8 | 49 | 13.5 | 41 | 11.3 |
| Victoria | 785 | 371 | 47.3 | 216 | 27.6 | 116 | 14.8 | 39 | 5.0 | 14 | 1.8 | 13 | 1.7 |
| Total and average. | 1,638 | 504 | 30.2 | 349 | 21.3 | 263 | 16.0 | 157 | 9.6 | 150 | 9.2 | 101 | 6.2 |

FEMALE WEEVILS.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dallas | 411 | 32 | 7.8 | 54 | 13.1 | 91 | 22.1 | 46 | 11.2 | 91 | 22.1 | 37 | 9.0 |
| Calvert | 352 | 67 | 18.8 | 63 | 17.7 | 60 | 16.7 | 58 | 16.3 | 54 | 15.2 | 32 | 9.0 |
| Victoria | 564 | 293 | 51.9 | 133 | 23.5 | 88 | 15.6 | 24 | 4.3 | 11 | 2.0 | 10 | 1.8 |
| Total and average. | 1,327 | 392 | 29.5 | 250 | 18.8 | 239 | 18.0 | 128 | 9.6 | 156 | 11.7 | 79 | 5.9 |

WEEVILS OF BOTH SEXES.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total and average, 2,967 | | 896 | 30.2 | 599 | 20.2 | 502 | 16.9 | 285 | 9.6 | 306 | 10.3 | 180 | 6.1 |

MALE WEEVILS.

| Locality. | Number of weevils in series. | Weevils dying within a period of— | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 61–70 days. | | 71–80 days. | | 81–90 days. | | 91–100 days. | | Over 100 days. | |
| | | Number. | Per cent. | Number. | Per cent. | Number. | Per cent. | Number. | Per cent. | Number. | Per cent. |
| Dallas | 490 | 36 | 7.3 | 31 | 6.3 | 5 | 1.0 | 7 | 1.5 | 2 | 0.4 |
| Calvert | 363 | 7 | 1.9 | 6 | 1.7 | 2 | 1.6 | 2 | .6 | 0 | ..... |
| Victoria | 785 | 4 | .5 | 8 | 1.0 | 3 | .4 | 0 | ..... | ..... | ..... |
| Total and average. | 1,638 | 47 | 2.9 | 45 | 2.8 | 10 | .6 | 9 | .6 | 2 | .1 |

FEMALE WEEVILS.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dallas | 411 | 32 | 7.8 | 22 | 5.4 | 4 | 1.0 | 1 | 0.2 | 1 | 0.2 |
| Calvert | 352 | 9 | 2.5 | 3 | .8 | 5 | 1.4 | 2 | .6 | 1 | .3 |
| Victoria | 564 | 4 | .7 | 1 | .2 | 1 | .2 | 0 | ..... | 0 | ..... |
| Total and average. | 1,327 | 45 | 3.4 | 26 | 2.0 | 10 | .8 | 3 | .2 | 2 | .1 |

WEEVILS OF BOTH SEXES.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total and average, 2,965 | | 92 | 3.1 | 71 | 2.4 | 20 | 0.7 | 12 | 0.4 | 4 | 0.1 |

At Dallas the number of weevils surviving for two months or more amounted to 15.6 per cent of the total number observed. Practically 50 per cent of each sex survived for more than six weeks.

At Calvert 15 per cent of the total number of weevils survived over fifty days and 50 per cent for more than thirty days. The average life at Calvert was nearly ten days less than at Dallas. It is very noticeable that those weevils which lived longest at Calvert emerged during about the middle of the emergence period. The weevils which were very late in emerging survived for only a short time. The decrease in the percentage of survival is markedly regular from the first ten days to the end of the period. The most decided decrease occurs between sixty and seventy days.

The maximum longevity at Victoria fell considerably short of that at Calvert and Dallas. In this case 15 per cent of the weevils survived beyond only about twenty-five days and nearly 50 per cent died during the first ten days. The reason for the marked shortening of life at Victoria was undoubtedly the greater exposure to sunshine of the jars in which the weevils were confined.

This comparison shows that length of life uniformly averages longer in northern Texas than in either central or southern Texas. At Dallas 3 weevils, at Calvert 1, and at Victoria none lived more than one hundred days. At Dallas 11 weevils, at Calvert 5, and at Victoria none lived more than ninety days. From the grand summary of the records in both sexes it appears that among approximately 3,000 weevils 50 per cent died during the first twenty days. Two-thirds of them died in the first thirty days and three-fourths of them in the first forty days.

From these records it appears that any kind of a food supply will serve to maintain a majority of the emerging weevils for more than three weeks. This consideration has a special significance in southern Texas, where sprout and volunteer cotton usually occur. This subject will be further considered in the relation of hibernated weevils to food supply.

### BEARING OF OBSERVATIONS ON FED AND UNFED WEEVILS ON THE POSSIBILITY OF AVOIDING DAMAGE TO COTTON BY LATE PLANTING.

One of the most important features of the experiments on the longevity, with and without food, of weevils that have survived the winter, is the bearing that the results have on the theory of late planting of cotton to avoid damage. This theory has been propounded by numerous persons ever since 1895.

In the series of experiments with unfed weevils 4,600 individuals were used; in the series with fed weevils 2,965. The unfed series is the more important with reference to late planting, The maximum length of life of the unfed weevils emerging in February, 1907, was

14 days; the average 6.9 days. The maximum of the individuals emerging in March was 51 days; the average 16.9 days. For the April-emerging weevils the maximum was 46 days; the average 21.2. For the May-emerging weevils the maximum 33; the average 15.8 days. Of the June-emerging weevils maximum 12 days; the average 7.4. It will be seen that even in such an abnormal season as 1907 weevils emerging any time during the month of May might be expected to live for at least 15 days and individuals emerging at any time during the month of June to live for more than 7 days. It is thus clear that many weevils emerging in May would survive without any food whatever until considerably after the middle of June and that those of the June emergence would survive in many cases beyond the first of July.

It is important to note that a considerable percentage of the emerging weevils did not appear until late. For instance, 10.2 per cent of all the weevils which survived at Calvert did not appear until between May 10 and June 6. At Dallas the percentage for this period was 7.5, and at Victoria, 2.38.

The observations on the longevity of the fed weevils also has a bearing on late planting, since there is always some volunteer cotton around seed houses and elsewhere that will be found by the weevils. The maximum length of life of the fed weevils which appeared in February was 47 days, the average 45 days; of March-appearing weevils the maximum 93 days, average 45.5 days; of April-appearing weevils maximum 82 days, average 46.5 days; of May-appearing weevils maximum 86 days, average 55 days; of June-appearing weevils maximum 46 days, average 37.8 days.

The longevity of the weevils emerging in May and June is most important. The average survival of 55 days in one case and the 37.8 in the other shows that with such food as can easily be obtained, at least some of the emerging weevils would be carried over until far into the summer, even if no cotton were planted.

The records just referred to are, of course, a sufficient refutation of the theory that the weevil could be "starved out" by late planting. It has been proposed, however, that the number of weevils surviving to damage late-planted cotton would be relatively so small that such cotton would have a better chance to mature a crop than that planted earlier. In order to test this matter the Bureau of Entomology has conducted practical field tests in which cotton has been planted about the 10th of June. In one season four of these experiments were performed in parts of Texas showing distinct climatic features and one in Louisiana in cooperation with the State Crop Pest Commission. In every case the yield was cut down so severely by the weevils that survived the prolonged period in which no cotton was to be found that the impossibility of producing cotton in that way was fully demonstrated.

## SEX OF WEEVILS SURVIVING HIBERNATION.

We found it possible to readily and accurately recognize male and female weevils without a partial dissection. In comparatively few species of weevils are the males and females so closely similar in general external character as in the case of the Mexican cotton boll weevil. It was found that size depended primarily upon the food supply of the larva and that it had no special significance in regard to sex, although it appears that the average male is slightly smaller than the average female. There exists a rather wide variation also in coloration, which also proved to depend upon food supply and age rather than upon sex.

### SECONDARY SEXUAL CHARACTERS.

We are indebted to Dr. A. D. Hopkins, of the Bureau of Entomology, for indicating the most strongly marked points of difference in the secondary sexual characters of the boll weevil. The distinctive

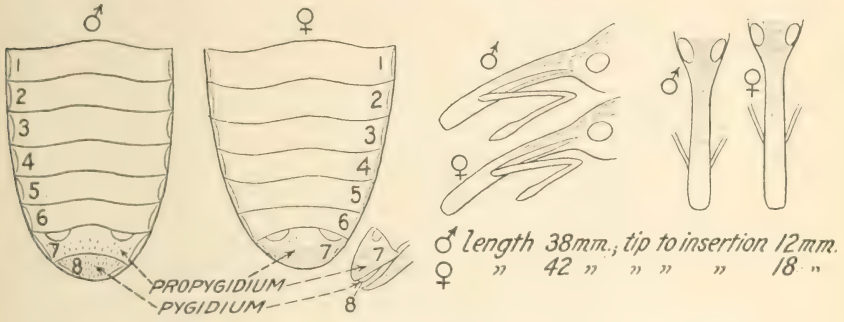



FIG. 9.—Secondary sexual characters of *Anthonomus grandis*. (After Hopkins.)

characters (see fig. 9) are found upon the snout and upon the dorsal side of the last two abdominal segments, which are normally almost completely hidden by the wing covers. The differences are subject to some variation but are still sufficiently constant to enable a close observer to positively separate males from females with the aid of a hand lens. Since these points of distinction have not previously been published it seems advisable to include them here, as they furnish the basis for the determinations of sex which follow.

*Female.*—The snout of the female is slightly longer and more slender than that of the male. It usually tapers slightly from each end toward the middle when viewed from above. The antennæ are inserted slightly farther from the tip than is the case in the male. The insertion is at about two-fifths of the distance from the tip of the snout to the eyes. As a rule the surface of the snout is more smooth and shining than in the male. A slight depression, rather elongated and much larger than any of the other punctures upon the

snout, occurs between the bases of the antennæ. When the wing covers and wings are unfolded the abdomen shows seven distinct dorsal segments. The last segment visible from above in the female is called the propygidium. In the female this covers the terminal segment or pygidium, which can be seen only from the sides.

*Male.*—Snout slightly shorter, thicker, and more coarsely punctured than in the female. The depression mentioned in the female is lacking. The antennæ are inserted at practically one-third of the distance from the tip of the snout to the eyes. The sides of the snout are very nearly parallel. In the abdomen the male shows eight distinct dorsal segments, the terminal segment (pygidium) not being covered by the propygidium as is the case in the female.

In general practice an examination of the snout is sufficient to determine the sex of each weevil.

### PROPORTION OF SEXES SURVIVING HIBERNATION.

The records here given as to the proportion of sexes surviving hibernation are confined to determinations of sex for positively hibernated adults.

TABLE XLVI.—*Sex of weevils surviving hibernation in Texas.*

| Year. | Locality. | Male. | | Female. | |
|---|---|---|---|---|---|
| | | Number determined. | Percentage of total examined. | Number determined. | Percentage of total examined. |
| 1903 | Several places | 269 | 60.7 | 174 | 39.3 |
| 1904 | Calvert | 40 | 60.0 | 27 | 40.0 |
| 1904 | Victoria | 42 | 66.7 | 21 | 33.3 |
| 1904 | do | 161 | 55.0 | 132 | 45.0 |
| 1906 | do | 84 | 59.6 | 57 | 40.4 |
| 1907 | Dallas | 1,668 | 54.2 | 1,412 | 45.8 |
| 1907 | Calvert | 948 | 53.0 | 846 | 47.0 |
| 1907 | Victoria | 1,660 | 61.3 | 1,049 | 38.7 |
| | Total and average | 4,872 | [a] 56.7 | 3,718 | [a] 43.3 |

[a] Weighted average.

While these records show considerable variation in the proportion of the sexes for different localities and during different seasons, there is a uniformity in the general preponderance of males. In the total of 9,000 weevils examined 53.6 per cent were males. This proportion corresponds quite closely to that found to exist among weevils entering hibernation (see pp. 16–17). It is evident, therefore, that the preponderance of males in the spring is not due to any superior power of endurance enabling them to hibernate more successfully than females. Apparently there is little, if any, difference in respect to the ability of the two sexes to hibernate successfully.

From a knowledge of the habits of the adults it appears that the preponderance of males in the spring is a favorable provision of nature, making it more certain for the sexes to mate and to insure reproduction. In spite of a number of attempts to obtain a definite answer to the question whether it is absolutely necessary for copulation to occur in the spring before females can reproduce, this point has not been positively settled. There are indications, however, that in most, if not all, cases this is essential. The fact that mating occasionally occurs immediately after emergence but before either sex has fed in the spring has previously been noted. Unfertilized females at any season of the year deposit nearly all of their eggs upon the outside of squares or bolls, where they quickly dry up. No sign of parthenogenesis has been found. The meeting of males and females is to a large degree accidental, and during a season when weevils are comparatively scarce it is likely that in very many cases the sexes fail to come together or the meeting may be delayed for a considerable period.

Experiments have shown that the male weevils do not actively seek the females. They seem to recognize their presence through a distance of hardly more than an inch. The meeting of the sexes depends therefore largely upon their coming into close proximity upon a cotton plant. Since the males are less active in their movement than are the females, the value of the existence of a majority of males becomes apparent. The larger number of males and the more active habits of the females serve to increase the chances for the meeting of the sexes in the spring without materially decreasing the power of multiplication of the species.

## RELATION OF HIBERNATED WEEVILS TO FOOD SUPPLY.

The relation of hibernated weevils to food supply is an important subject, since the reproduction and multiplication of the species depend primarily upon this point. As has been shown in numerous places the emergence period of the weevil practically coincides with the average period in the planting of cotton. The long duration of emergence makes it practically impossible to secure the planting of the entire crop either earlier or later than the emergence period of the weevil. It has been found both from the study of the weevil and from large-scale experiments in the culture of cotton that during nearly every season there is a decided advantage in planting the crop as early as soil and climatic conditions may permit. Too much emphasis can not be placed upon the fact that, at whatever time the cotton in a locality may be planted, there will be a decided advantage in having it all planted at as near a uniform date as is possible. It is obvious that this will entirely prevent the development of weevils until practically all of the crop begins fruiting. In this way the fruiting of the

plant may take place most rapidly during the period of development of the first and second generations of weevils.

Early planted fields, although they may serve to attract, in some small degree, the weevils from surrounding fields, will almost invariably produce larger yields than later planted fields in the same locality. The reason for this is, primarily, the longer period which intervenes between the beginning of setting fruit with its coincident reproduction of weevils and the time when maximum infestation of the field occurs. Comparatively few weevils appear to move from one field of cotton to another until after maximum infestation takes place.

Repeated experiments in deferring the planting time of cotton have invariably resulted in small and comparatively unprofitable crops.

Extended observations made during the spring of 1906 showed that volunteer[a] cotton occurred very commonly in fields and yards, along roadsides, and around ginneries and seed houses in every one of the seventeen localities examined about the middle of May, representing territory then infested by the weevil and also extending outside the infested territory into Mississippi, Arkansas, and Tennessee. This makes it practically certain that volunteer[a] cotton occurs everywhere throughout the cotton-growing area, and it may therefore have considerable significance in supplying emerged weevils with their first food in spring.

Extensive examinations have also shown that sprout[a] cotton commonly occurs throughout the southern half of the weevil-infested area in Texas during the average season. As a rule the development of this takes place several weeks in advance of the average planted cotton, and it becomes therefore a very important factor in maintaining hibernated weevils and in the development of their first progeny. Although attention has repeatedly been called to this fact, large quantities of sprout cotton are still allowed to grow unchecked. It is doubtful whether it is advisable to cultivate this even where it amounts to half a stand. Wherever scattering plants occur in a field of planted cotton they should certainly be chopped out as quickly as they occur. The profit to be derived from them is nothing when compared with the great damage which their presence may inflict upon the remainder of the crop through providing the earliest opportunities for the reproduction and multiplication of the weevils.

[a] The term "volunteer" is restricted to that class of cotton coming from the accidentally scattered seed of a preceding crop. Sprout cotton, also called stubble or seppa cotton, is a sprout growth from old cotton roots occurring during the winter or subsequent spring.

## SUMMARY AND CONCLUSIONS.

Hibernation is the term used to designate those phases in the life and seasonal history of the boll weevil (or of any other animal or plant) which are concerned with its existence through the winter and the manner in which the species is protected or maintained in passing from one season to the next. Food, climatic, and shelter conditions are the principal factors concerned in hibernation.

Food conditions in the fall govern largely the abundance of individuals which may enter hibernation and therefore affect the abundance of the species in the following spring, since climatic and shelter conditions govern largely the proportion of the hibernating individuals which may survive.

A large majority of the weevils developed in a field during the season are produced from squares.

Weevils becoming adult comparatively late in the season are more likely to survive hibernation than are those which have been active for a number of weeks before the time arrived for them to hibernate successfully.

It is possible that offspring of each of the four or five generations which are produced on the average may survive to enter hibernation.

No "top crop" can reasonably be expected within the weevil-infested area.

All stages of the weevil may enter hibernation and under exceptionally favorable climatic conditions larvæ which are more than half grown may complete their development if in bolls and become mature during the hibernation period. Immature stages in squares rarely survive. Nearly all of the weevils surviving were adult before the beginning of the hibernation period.

The destruction of stalks in the fall, as long as possible before the normal hibernation time, is the most economical and effective method known for reducing the number of weevils entering hibernation.

"Entrance into hibernation" denotes the beginning of the generally inactive period, but it does not necessarily imply a change of position for the individuals involved. For the species and often also for the individual it is a gradual process depending primarily upon temperature conditions. The duration of the entrance period for the species depends upon the severity of the drop in temperature below about 43 degrees of mean average temperature. This period usually occurs coincidently with the first killing frosts and extends through a period of about twenty-five days.

From close examination of 1,750 weevils it seems that about 60 per cent of those entering hibernation are males.

The number of weevils per acre or per plant which may enter hibernation depends especially upon preceding climatic and food conditions

and has been found to vary in different seasons and localities, occasionally being as high as 50,000 weevils per acre, or an average of from 7 to 10 weevils per plant. An average of the results in 17 of the most carefully studied fields shows 8,552 weevils per acre, or slightly more than 1 weevil per plant.

The proportion between the numbers of weevils hibernating on the stalks and among rubbish scattered on the surface of the ground changes as the season advances, the number on the stalks decreasing.

Great mortality occurs soon after the weevils enter hibernation, especially among those upon the surface of the ground.

Hibernation usually takes place as the mean average temperature falls below 55 degrees and may remain complete until the mean temperature rises above 60 degrees.

Weevils may avail themselves of almost any kind of shelter, and the favorable character of the shelter in relation to prevailing climatic conditions will influence the percentage of survival. Many pass the winter sheltered by the old bolls that remain hanging upon the stalks. The percentage of survival in bolls decreases generally from southern to northern Texas. Bolls are frequently so important a factor in shielding weevils from one season to another that it is advisable to destroy them as a regular practice even in northern Texas.

Exceptionally cold and wet winter weather is most unfavorable for weevil survival. The destruction of possible shelter through clean culture in the fall is an effective way of reducing weevil injury to the following crop. The shelter to be found in timber fringes around cotton fields is much more difficult to remove or control than is that within the fields. The importance of such unavoidable conditions may be minimized by judicious cleaning up and by rotation of crops.

Occasionally weevils may survive in stored cotton seed and be distributed along with it at planting time. This fact justifies the maintenance of quarantine regulations against the free movement from infested to uninfested territory of cotton seed and closely related cotton products which are apt to shelter weevils.

Most of the information obtained in regard to the hibernation of the weevil has resulted from cage experiments in which the influential conditions could be separated and to some degree brought under control.

During the winter of 1902–3, at Victoria, Tex., in the small-cage experiments with 356 weevils, an average of about 11 per cent survived. During the following season, also at Victoria, among 400 weevils but one-fourth of 1 per cent survived. During the winter of 1904–5 larger numbers of weevils were under observation at each of six localities ranging from the southern to the northern portions of

the infested area. This was the season of most exceptional rainfall and cold, and it was not surprising that no weevils survived in the cage tests except at Victoria, which was the southernmost point of experiment. An average for the six localities shows a survival of less than two-thirds of 1 per cent. In the small-cage work of 1905–6 there was an average survival of 1.3 per cent, and practically all of this occurred in the outdoor cages.

The most important work done in 1905–6 was in a large cage at Keatchie, La., where 25,800 weevils were placed in 18 compartments. The survival in this cage was 2.82 per cent, and the emergence occurred between March 22 and June 28, 1906. The cages having nearest to the ordinary field conditions with poor cultivation gave the largest percentage of successful hibernation. A study of the emergence and temperature records for similar experiments at Dallas, Tex., and Keatchie, La., shows that at the former place approximately 50 per cent of the emergence occurred while the temperature ranged between 58 and 68 degrees, while at the latter place one-half of the total emergence took place while the temperature ranged between about 65 and 75 degrees. Very few weevils emerged while the temperature was below 57 degrees.

There is an optimum period for entrance into hibernation, and weevils entering during this period have a considerably better chance of surviving than do those which enter either earlier or later. If hibernation is begun earlier than this optimum period, it is likely that emergence will be completed earlier during the following season, and also if entrance occurs later than this period it is likely that emergence will begin unusually early in the following spring.

Variation in the period of entrance into hibernation and the difference in the nature of the shelter secured by the weevils may reasonably account for the variations found in the amount of accumulated effective temperature required to produce complete emergence in the spring.

Weevils emerging earlier in the season survived for a longer period than did those which emerged after the middle of the emergence period. It is a common occurrence for weevils to leave their winter quarters upon warm days in spring, returning again to a condition of inactivity for a period of several days or even weeks. Disappearance and reappearance in the case of plainly marked individuals has been observed to occur as many as eight times, and a maximum period of forty-three days between appearances has been recorded. These facts argue very strongly indeed against the proposition which is sometimes made by those who are not thoroughly familiar with the habits of the weevil, to starve the emerged weevils by deferring the planting of cotton in the spring. Two lots of 20 and 8 weevils sur-

vived for an average of thirty and sixty days, respectively, after emergence without a particle of green food from the time of their entrance into hibernation to the time of their death. Other tests show similar results.

The hibernation experiments of 1906–7 consisted of large-cage work in three localities representing the northern, central, and southern portions of the infested area. Each cage inclosed 10 separate experiments and the comparisons made possible by the three locations, the different shelter conditions, and the different dates of instituting the experiments furnish the basis for the most complete and significant work which has been done with the hibernation of the weevil.

Owing to the exceptional mildness of this season, complete hibernation did not occur at any time during the winter in any part of Texas. Emergence began during the last week or ten days of February, 1907. At Dallas 7.8, at Calvert 10.5, and at Victoria 27.7 per cent of the total numbers of weevils placed in the cages were counted as being active at some time during the winter season when they should normally have all been in complete hibernation. About 13 per cent of the adult weevils buried with a lot of bolls under 2 inches of heavy, black soil escaped and were found upon the cage screen during the next few days. Weevils were active in the field as well as in the cages during this winter. The period of greatest emergence occurred during the latter part of March, which was undoubtedly from four to six weeks earlier than is usual. Succeeding low temperatures served to prolong the period of emergence until the 1st of July. In the three localities under observation an average of 11.5 per cent of the 75,000 weevils placed in the experiments survived and emerged in the spring of 1907.

Grouping the experiments in the three localities according to the dates of installation of the weevils and averaging the percentages of survival in each group, it appears that there was a steady increase in this percentage upon succeeding dates after the middle of October, when the experiments were started, to the end of November, when the last weevils were placed in the cages. This increase is so nearly regular as to prove conclusively that the date at which weevils are deprived of food in the fall, in its relation to the most favorable period for entrance into hibernation, has a most vital influence upon the prospect for survival. Among the weevils started October 14 but 3.14 per cent survived, while among those started just one month later an average of 19.67 per cent survived. These results prove absolutely the advisability of destroying the food supply of the weevils at least three weeks before the usual time for the first frosts to occur, and they show very plainly just why such a practice is the

most effective method yet found for reducing the number of weevils that may survive the winter to attack the crop of the following season. This portion of the bulletin, especially, should be carefully studied in detail.

The survival in the various sections of the cages in the three localities ranged from 1.89 to 31.34 per cent. The average survival in each of the localities was as follows: Calvert, 9.49 per cent; Dallas, 11.22 per cent; Victoria, 13.47 per cent.

At Dallas the largest percentage of survival occurred in a section of the cage having an abundance of fallen leaves, in which the weevils were placed on November 15 and with the cotton stalks left standing. The smallest survival occurred in a section having fully as favorable shelter conditions but in which the weevils were placed on October 13 and left without any food from October 15.

At Victoria the largest survival occurred among weevils started on November 6 without food in the section provided with Spanish moss and bark.

The winter was too mild to furnish any comparative test of the favorableness of various shelter conditions, but in general it appears that fallen leaves, Spanish moss, and a heavy growth of grass are most favorable to the weevils wherever they may occur.

Temperature conditions were practically normal during November, 1906, and the most favorable time for entrance into hibernation was between November 12 and 15 at Dallas and slightly later at the more southern points.

In each locality the maximum longevity was shown by males, and the average duration of life of that sex was also slightly in excess of that of females. The average survival of all weevils kept without food was about ten days, and a considerable number lived to between six and twelve weeks after emergence. The maximum survival for any unfed weevil was ninety days. Obviously there is no chance to starve out all weevils by any possible delay in planting.

Among the fed weevils the longest-lived was also a male which was active for one hundred and thirty days after its emergence. The longest-lived female was active for one hundred and eighteen days. The average active life for all fed weevils was 25.5 days after emergence. Practically one-half of all fed weevils lived for more than six weeks in the spring.

The sex was determined for more than 8,500 weevils which had survived the winter, and it was found that 56.7 per cent of these were males. There is an invariable preponderance of males both in the fall upon entering hibernation and in the spring upon emergence therefrom.

Reproduction can not begin until the first squares become at least half grown. At whatever date cotton may be planted in a locality,

there is a decided advantage in having it all planted at as nearly a uniform date as is possible. As a rule early-planted fields yield better than do those planted later, but with similar conditions of seed, soil, and cultivation. All volunteer and sprout cotton developing in advance of the main crop should be destroyed before it forms squares, since otherwise it may furnish the weevils with opportunities for reproduction for some time before squares become common and thereby unnecessarily, early in the season, increase their numbers and the resultant injury to the main crop.

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